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W. J. Ozga

TECHNICAL BULLETIN NO. 84
(Résumé en français)

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
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Cat. No.: En 36-503/84

Contract No. KL 327-4-8069
THORN PRESS LIMITED

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Abstract

Automated data processing techniques were introduced in the Water Survey of Canada in 1966 along two fronts: (a) computation of streamflow data using a digitizer, and (b) storage of hydrometric data on magnetic tape.

General procedures for the collection, computation and publication of basic hydrometric data are explained. However, the main purpose of this report is to summarize the events leading to automation and the factors and problems involved in the selection and implementation of the system as it now exists.

Résumé

Des techniques automatisées pour le traitement de l'information ont été introduites, en 1966, à la Division des relevés hydrologiques du Canada. Elles ont porté sur deux plans: (a) le calcul des données sur l'écoulement à l'aide d'un convertisseur numérique et (b) le stockage de données hydrométriques sur rubans magnétiques.

Les méthodes générales de collecte, de calcul et de publication des données hydrométriques fondamentales sont décrites. Cependant, le but principal de ce rapport est de faire le résumé des événements qui ont conduit à l'automation, ainsi que des problèmes et des facteurs relatifs au choix et à la mise en oeuvre du système tel qu'il existe.

Glossary

Computer Program — a sequence of instructions that tell a computer exactly how to handle a specific procedure or problem. A computer language is a defined set of rules for communicating with a computer, e.g. COBOL, FORTRAN, ALGOL, PL/1, assembler.

Discharge Measurement — the determination of the rate of flow of water in a river, using specialized equipment to measure the width and depth and the velocity at several points in a cross-section.

Flowchart — a graphic representation of the logic sequence of procedural steps by which data are processed.

Gauging Station — a location where systematic records of stage and/or discharge (streamflow) are obtained; also referred to as a ''Hydrometric Station''.

Hydrograph — a graph showing the stage, discharge, velocity or some other property of water in relation to time.

Hydrometric Data — a numeric record of surface water flow and/or water level of rivers and lakes. Data are expressed in various time intervals, e.g. instantaneous, daily, monthly or annual.

Magnetic Tape — a plastic half-inch wide tape coated with ferrous oxide which permits retention of small magnetized areas which are recognized as characters by a computer. A character (or byte) is represented by specific combinations of bits along 7 or 9 tracks (or channels). Data density is identified as bpi (bytes per inch), usually 556, 800 or 1600.

Optical Character Recognition (OCR) — the identification of graphic characters, typed in a specific font and format, by a photosensitive device (Page Reader); the characters are translated and used directly for computer processing.

Pencil Follower — a manually-operated electronic device which converts data on maps, drawings or analog charts to digital form for computer processing; also called a ''digitizer''.

Photocomposition — the exposure of character images from magnetic tape onto photosensitive paper using a digital computer and a cathode ray tube printer.

Stage — the height of the water surface as referred to a standard datum; used interchangeably with ''gauge height'' and ''water level''.

Stage-Discharge Relationship — the relation between the water level and the discharge at a gauging station, expressed as a volume per unit of time.

Water Level Recorder — an instrument that records water levels in graphical or digital form. It may be actuated by a float or by any one of several pressure systems.

Introduction

The Water Survey of Canada has been collecting and publishing streamflow and water level data on a regular basis since about 1908.

The present active hydrometric network consists of approximately 2300 gauging stations, excluding those operated by the Province of Quebec who have conducted their own hydrometric surveys since 1964 and excluding also some 200 stations for which data are supplied by cooperating agencies. Basic data are collected and computed by District Office personnel at Vancouver, Calgary, Regina, Winnipeg, Guelph and Halifax and an Area Office at Montreal. The computed data are forwarded annually to Ottawa, where they are stored on magnetic tape and made available in published form. In 1973, the total staff engaged in these surveys in the Districts and in Ottawa was approximately 330.

Water data are essential for evaluating water supplies for cities, industries, irrigation and recreation; designing structures to control and conserve water; developing guidelines for provincial, national and international administrations regarding licencing and permits for water use; determining potential hydropower; flood frequency studies; water quality monitoring; geomorphological studies; and for other types of water management studies. For some of these uses, data are required on demand, for others at intervals of a few days or a few months and for others such as design and research, the data are most useful after several years of record have been obtained.

The user must know what records are available and the system must allow him to extract specific information for analysis. He usually needs this information quickly. To achieve the full benefits from complex statistical and analytical techniques, the data must be available in computer-compatible form. With these considerations in mind, the Water Survey of Canada decided in 1966 to develop automated methods to improve the service to data users. The Data Control Section in Ottawa was established to develop, implement and control standard procedures for the computation and publication of hydrometric data; to supply data on punched cards or magnetic tape for computer processing; to maintain a Gauging Station Inventory; and to review historical hydrometric data to expose significant errors in original computations and interpretations.

Automated procedures for the computation and publication of hydrometric data are now operational in all Districts. The purpose of this report is to summarize the events leading to automation and the factors and problems involved in the selection and implementation of the system as it now exists.

Hydrometric Field Procedures

Since this report contains a description of the various factors involved in the development of automated procedures for handling data, it would be useful to review briefly the techniques and considerations involved in the field work that generates the data.

SELECTION OF GAUGING STATION SITE

Streamflow data are often required at a site where certain hydraulic conditions are not suitable for an ideal hydrometric station.

The site for measurement of stage should be close to the site for measurement of discharge and should have the following ideal characteristics:

1. Stable channel bed and banks (not subject to scour or deposition).
2. In a straight reach, preferably in a pool upstream from a natural riffle or rapids (not subject to reverse flow or angle of flow or bank overflow during flood flows) and suitable for locating two or more auxiliary gauges to determine water slope if required.
3. Suitable for installation of an artificial control, if desired.
4. The discharge measurement section should be suitable for wading (for low flows on small streams), measurement through an ice cover, installation of a cableway and there should be no significant inflow between the measurement section and the gauge location.
5. Far enough upstream from a confluence with another stream to avoid backwater conditions.
6. Uniform vertical and transverse velocity and depth distribution (velocity not too slow, depth of water not too shallow or irregular and stream not too wide if also shallow).
7. Other factors to be considered are:
   (a) accessibility by road or air, particularly during winter or flood periods,
   (b) availability of hydropower or telephone lines,
   (c) availability of an observer.

Of course, all these conditions are almost never present at any one location. In any case, gauging sta-

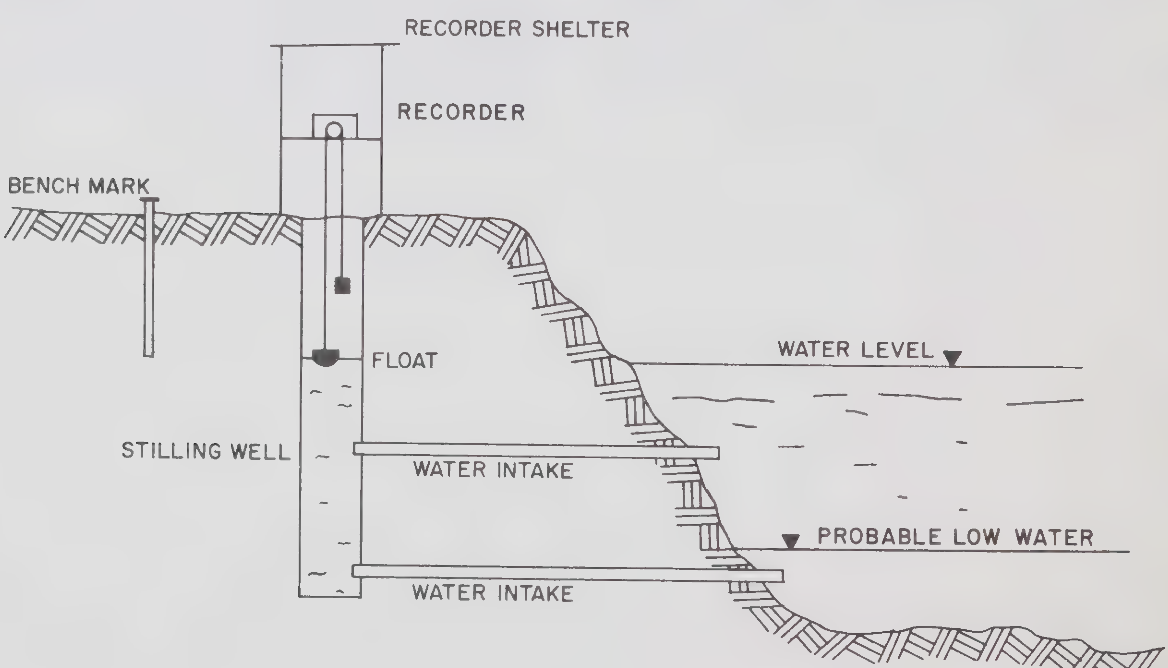

Figure 1. Typical field installation.

tions must be visited periodically to ensure that accurate records are obtained. Therefore, availability of staff and funds have a direct bearing on the reliability of hydrometric data.

DESCRIPTION OF FIELD INSTALLATION

A typical field installation consists of a manual or recording gauge to obtain a water level record and a bench mark to maintain the gauge datum (Fig. 1). Discharge measurements are made by wading, or from an ice cover, bridge or cableway (Figs. 2 and 3), by boat or catamaran, or by indirect determination. An artificial control may be constructed to stabilize the stage-discharge relation during low flows. The stage-discharge relationship at a gauging station is usually illustrated by a curve plotted through points representing measured discharges for corresponding water levels over the entire range of stage for the station (Fig. 4). By means of this curve, the discharge at the station at any particular time can be determined, once the relationship has been established, simply by reading the discharge from the curve opposite the water level at that time. Allowance must be made of course for conditions at the site which may from time to time affect the stage-discharge relationship.

Manual gauges are usually read once daily by an observer (more frequently during flood periods) and this reading is assumed to represent the mean water level for the day. Retransmission of water levels by satellite is now in the experimental stage. Water levels may be measured by any of the following methods:

1. Graduated staff gauge installed in the stream or on a structure.

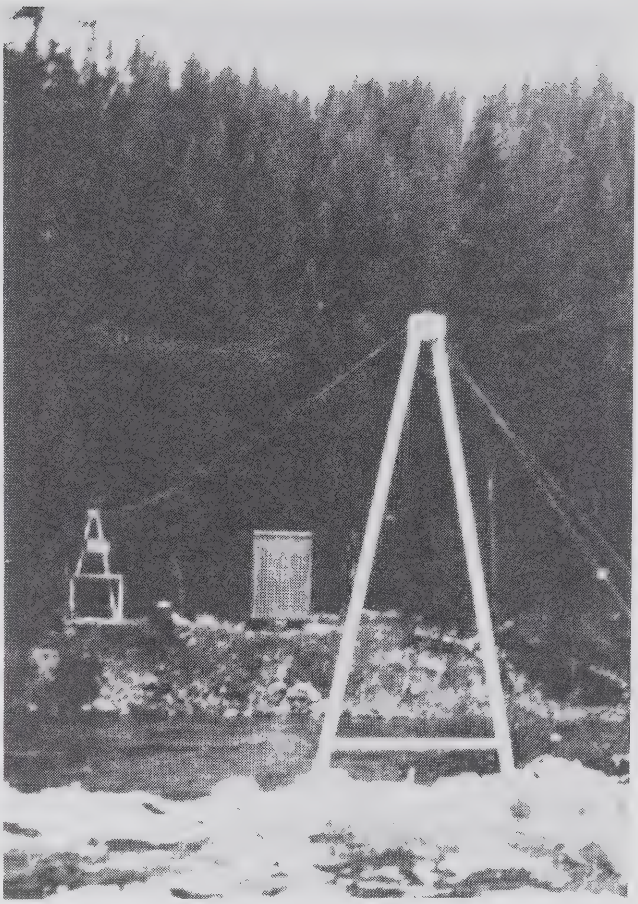

Figure 2. Gauging Station.

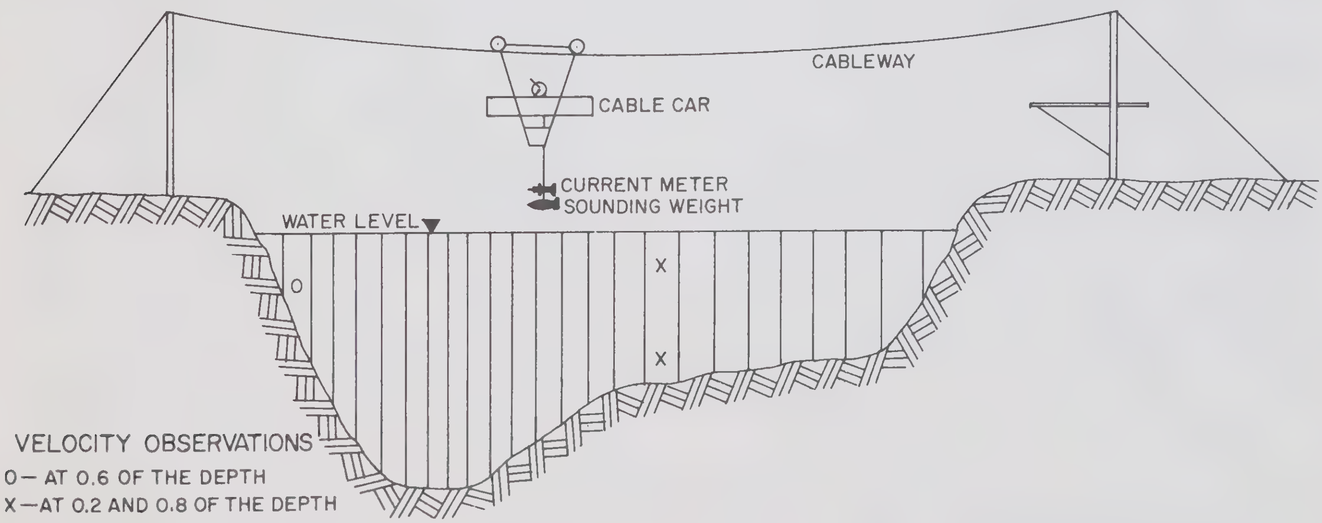

Figure 3. River cross-section showing distribution of observation points.

2. Slope gauge (an inclined staff gauge installed on the river bank).
3. Wire-weight gauge mounted over the water surface on a bridge or as a cantilever on the river bank (another variation is the electric tape gauge).
4. A reference point on a structure may be used to measure the distance to the water surface by means of a graduated rod or tape. The water level may also be determined by precise levelling from a bench mark.

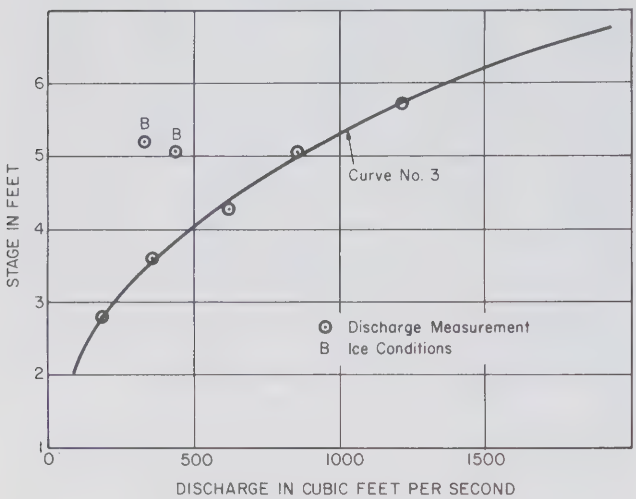

Figure 4. Stage-discharge relationship.

There are two basic types of water-level recording gauge, graphical and digital. The graphical Stevens type A-35 (Fig. 5) or the more recent A-71 recorder has been selected as the standard in the Water Survey of Canada. The scales most commonly used are 1:6 for stage and 2.4 in./day for time. The recorder (either graphical or digital) may be actuated by a float or pressure system. The float-actuated type requires the installation of a stilling well and intake, usually a flushing system and possibly an oil cylinder, frost floors or heating cables for winter operation. Several pressure-actuated systems are in use, all of which require the purging of gas (usually dry nitrogen) from a fixed orifice in the streambed. The static pressure in the gas purge system is proportional to the head of water over the orifice. This pressure is converted to pen movements by a servomanometer, a pressure bellows, or a servo-beam balance.

DETERMINATION OF STREAM DISCHARGE

Discharge measurements are required to define the stage-discharge relation or to determine the shift or backwater effect. In simplest terms, the discharge of a stream at a particular site at a specific time is the product of the cross-sectional area and the velocity of the water through it and is expressed as cubic feet per second. These discharge measurements, stage records and levelling results are used in computing a continuous record of daily discharges, from which values of monthly, annual and long-term means are derived.

Discharge measurements are made by the current meter method, tracers, volumetric method or by indirect determination. Various techniques for indirect determination are used with varying degrees of reliability, among them the slope-area method, dye dilution, flow over dams or weirs, etc. The current meter method is by far the most commonly used and requires the measurement of stream velocity and depth at selected verticals in a cross-section. The Price No. 622 Type AA current meter is the standard in use in the Water Survey of Canada for measuring stream velocity. Velocity observations are obtained in at least 20 verticals in the cross-section at 0.2 and 0.8 of the depth below the water surface; in shallower water one observation is obtained at 0.6 of the depth. The average of the 0.2 and 0.8 observations or the single observation at the 0.6 depth is taken as the mean velocity in the vertical (Figs. 3 and 6). The width of each segment is measured by tagline or from markings on the cableway or bridge; the depth is determined by graduated rods where measurements are

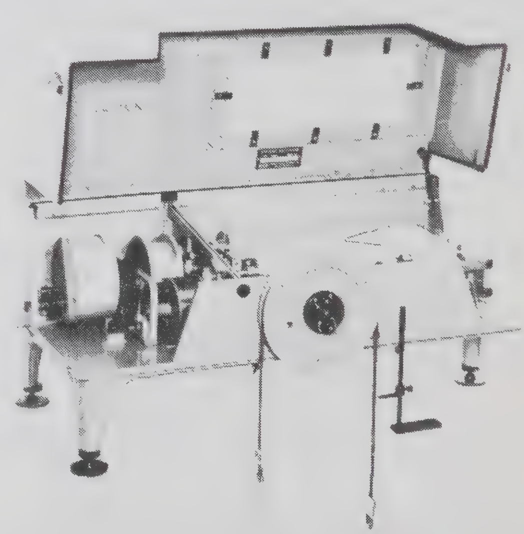

Figure 5. Water level recorder (Stevens Type A-35).

made by wading or from an ice cover, otherwise by using sounding weights suspended from a measuring crane. The flow in each segment is computed from these observations; the summation of the flow in each of these segments gives the total flow in the cross-section.

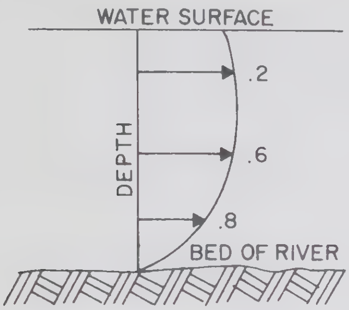

Figure 6. Vertical distribution of velocity.

The measurement of stream discharge is particularly difficult during flood periods, in tidal reaches and during winter conditions (especially if slush is present).

DESCRIPTION OF BASIC HYDROMETRIC DATA

About ten discharge measurements are obtained annually at each streamflow gauging station. Various parameters are measured, the results of which, although they are not published, are available to the user. The parameters are as follows:

1. Depth of water for at least 20 points to obtain the cross-sectional area of a river.
2. Velocity observations in each vertical where the depth is measured.
3. Air and water temperature at the time of the measurement.
4. Ice thickness in the cross-section.

Two types of water level records are obtained at the field installation:

1. Continuous graphical charts using a water-stage recorder (Fig. 7).
2. Individual water level readings, usually once or twice daily, by an observer living near the gauging station.

The following hydrometric data are computed, either manually or by computer program, from the basic field observations:

1. Daily water levels and daily discharges.
2. Instantaneous water levels and/or discharges at selected time intervals (usually hourly). Although these may be extracted manually from graphical charts, they are also available automatically if these charts have been digitized.
3. Annual maximum instantaneous water levels and/or discharges.
4. Daily discharges are used to give tabulations of annual maximum and minimum daily discharges, monthly and annual means in cfs and total ac-ft, and long-term means. These are obtained using computer programs.

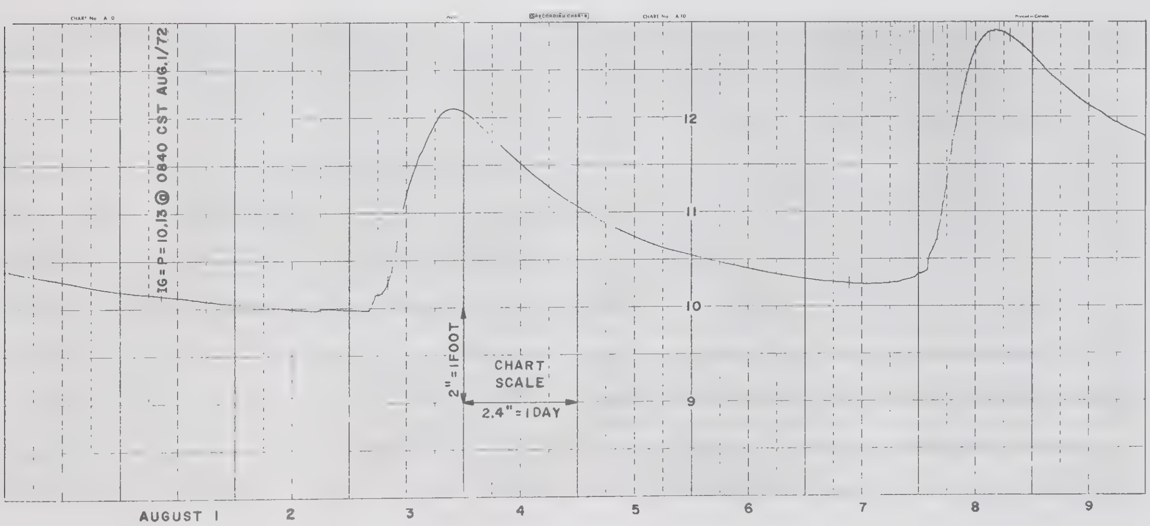

Figure 7. Water level chart (reduced from original size).

History of Automation

BACKGROUND

In the early sixties it became apparent that improved services had to be provided to users of hydrometric data. Automation was the obvious answer to reduce the delay between gathering and publishing data and to provide the data in a form more readily usable by computers, which were being used increasingly for hydrologic studies involving large amounts of data. Figure 8 shows the rate of growth in the number of gauging stations. Evaluation and selection of an automated data processing system, however, was influenced by various constraints and guiding principles.

The Water Survey of Canada is grateful to the United States Geological Survey for their cooperation, advice and assistance during evaluation of various systems and procedures. The USGS adopted and started implementing a digital recorder system about 1960; about the same time they also started storing streamflow data on magnetic tape. Through correspondence and also during visits to Washington from 1965 to 1967, the Water Survey of Canada gained considerable knowledge about automated data processing techniques, problems and pitfalls. Mainly because of computer incompatibility and departmental constraints, however, USGS computer programs could not be used on the computer available to the WSC (the USGS was reorganizing its computer services and using PL/1 as the programming language).

During 1965-66, two approaches to automation of daily discharge computations were considered: (a) to replace 800 graphical recorders with digital recorders; or (b) to retain the graphical recorders and digitize the resulting strip charts. When the USGS selected the digital recorder system, digitizers without overhead impediments had not been developed — some agencies in the USA are now using digitizers for streamflow computations. In any case, it should be recognized that conditions in Canada and the USA are not the same from a data collection point of view, and that certain factors such as cold weather operation, accessibility of stations, price of equipment, type of installation, etc. would affect the evaluation to a different degree; and also that a digitizer (without overhead arms) was not available until the mid-sixties. At the time, the reliability of the analog recorders in use was significantly greater than that of the digital recorders.

Finally, when additional staff and funds were provided in 1966, the Water Survey of Canada embarked on the implementation of two major aspects of automation:

1. Computation of daily discharges using a digitizer.
2. Storage and retrieval of historical hydrometric data on magnetic tape.

GUIDING PRINCIPLES

The main guiding principle in the selection of an automated system was that existing equipment and procedures should be used as much as possible and that the computer should be used as a tool to achieve the desired improvement in service to users of hydrometric data.

Further, computer programs should be as machine-independent as possible, especially for scientific or digitizer applications, and should be written to reduce complexity in keypunching instructions, procedures for documenting and digitizing recorder charts and any set-up for computer runs.

Data computations would continue to be performed at the District Offices and data files and publications would continue to be handled at Ottawa.

The system introduced many years ago for identifying gauging stations has been retained and is being used also in the storage and retrieval of data. Each gauging station is assigned a unique seven-character identification. The station numbering system begins with the division of Canada into eleven major groups of river basins. These main divisions are subdivided following heights of land within the division, with a letter assigned to each subdivision. Each subdivision is further divided on drainage basin boundaries and assigned a second letter, e.g. 5BD. Stations in this sub-subdivision are then assigned numbers in chronological order of date of establishment, independent of stream order. Thus, using the seven-character identification system, 05BD007 is the seventh station established in sub-subdivision 5BD; 11AA033 is the thirty-third station established in sub-subdivision 11AA, and so on.

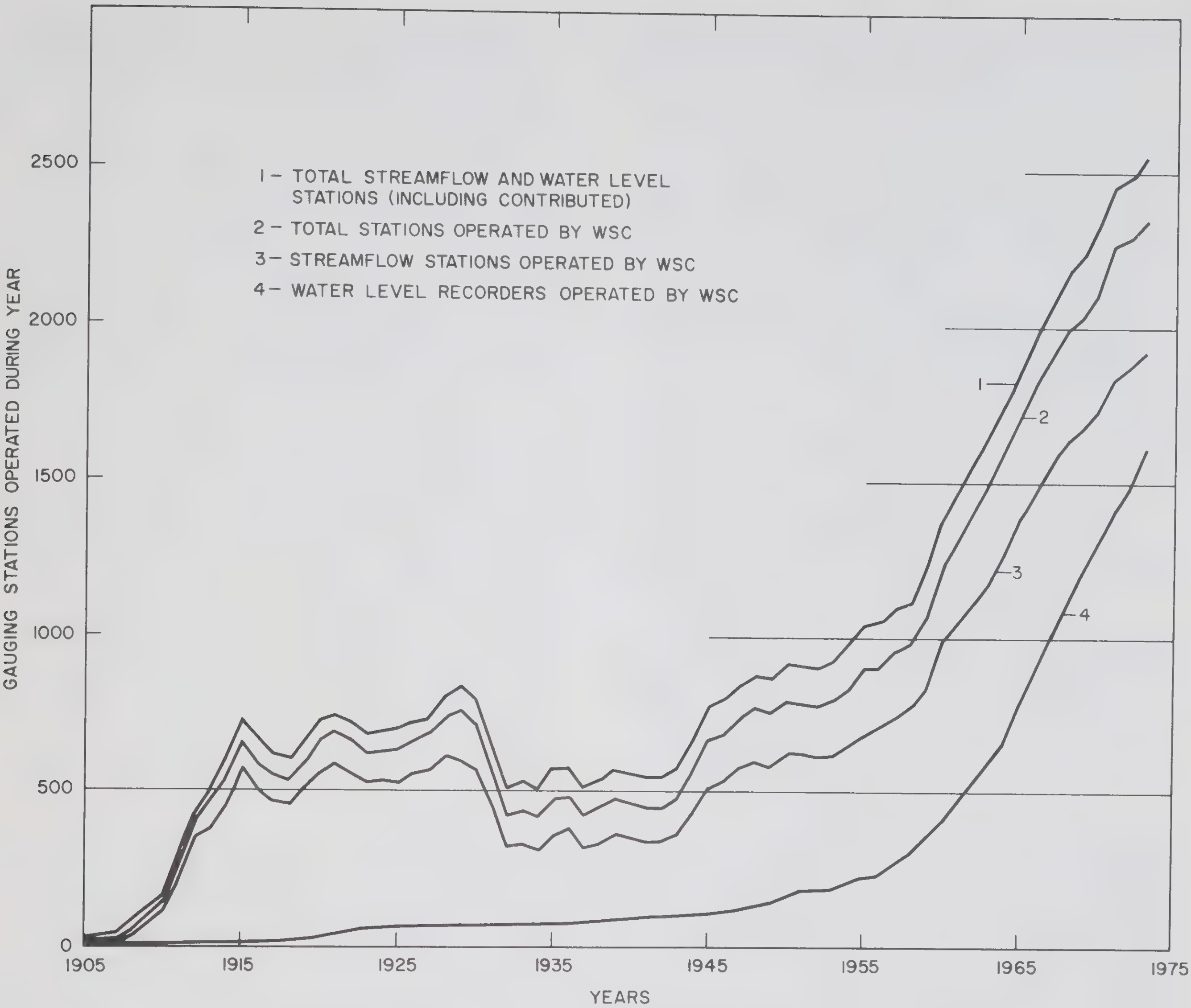

Figure 8. Gauging stations operated during history of hydrometric surveys in Canada.

GENERAL DESCRIPTION OF DIGITAL RECORDER SYSTEM

During the late fifties and early sixties, the USGS developed and implemented an automated system for the computation of streamflow data, the basic components of which are a digital-stage recorder, a paper-tape translator and a general-purpose digital computer.

The digital recorder is a battery-operated slow-speed paper-tape punch which records a 4-digit decimal number on a 16-channel paper tape at pre-selected time intervals. The paper-tape format is a unique configuration which requires rearrangement (translation) for input to any digital computer. The digital recorder can also be operated from other types of power supplies. Other digital recorders are now available which punch data on 5-channel paper tape suitable directly as input to digital computers. Briefly, the digital recorder system investigated for possible use in Canada in 1965-66 was as follows:

1. River stage would be punched, usually at 15-minute intervals, on 16-channel paper tape by the digital recorder in the gauge shelter. The tape would be removed by field personnel every 1 — 2 months.

2. The tape, tape corrections, gauge and shift corrections, and the appropriate stage-discharge table would be forwarded to Ottawa or a Regional Office from the District Office.

3. The data from the 16-channel tape would be translated onto 7-channel paper tape suitable for

input into the digital computer. The information on corrections and the stage-discharge table would be manually punched on paper tape with an add-punch machine. These two tapes would comprise the input data to the computer.

4. The computer would convert each instantaneous reading of river stage to a discharge value by a table look-up routine. Daily mean values of gauge height, discharge and equivalent gauge height would be stored on magnetic tape. The printed output from the first computer pass would consist of a primary computation sheet and/or a daily discharge sheet.
5. The primary computation sheet would give for each day, the maximum, minimum, and mean gauge heights, equivalent mean gauge height, gauge and shift correction applied, and the daily discharge. In addition, bi-hourly gauge heights would be printed and identified when the difference between successive gauge heights is greater than a specified control value, usually 0.2 ft.
6. The District Offices would use the primary computation sheet in quality checks of the original and computed data, and submit updating corrections to Ottawa or the Regional Office as required.
7. The final printout of the daily discharges (one page for one year) would be suitable for outside distribution or direct offset reproduction for publications. Daily discharges would also be stored on magnetic tape.
8. Data for those stations which would not be equipped with digital recorders, i.e. those equipped with graphical recorders or manual gauges, would be computed manually by the Districts. The OCR method (Optical Character Recognition) or punched card would be used for converting data to magnetic tape. For the OCR method, the data would be typed in a special format by the Districts. This page would then be forwarded to Ottawa where it would be scanned by a Page Reader, converted to magnetic tape, and printouts of daily discharges suitable for publication would be produced.
9. The Alphatext method of automated photo-copy preparation could be introduced where feasible.

GENERAL DESCRIPTION OF DIGITIZER SYSTEM

The Pencil Follower Unit consists of a digitizing table, control console and a card punch (Fig. 9). There is an auxiliary keyboard on the digitizing table which is used to enter program instructions on punched cards.

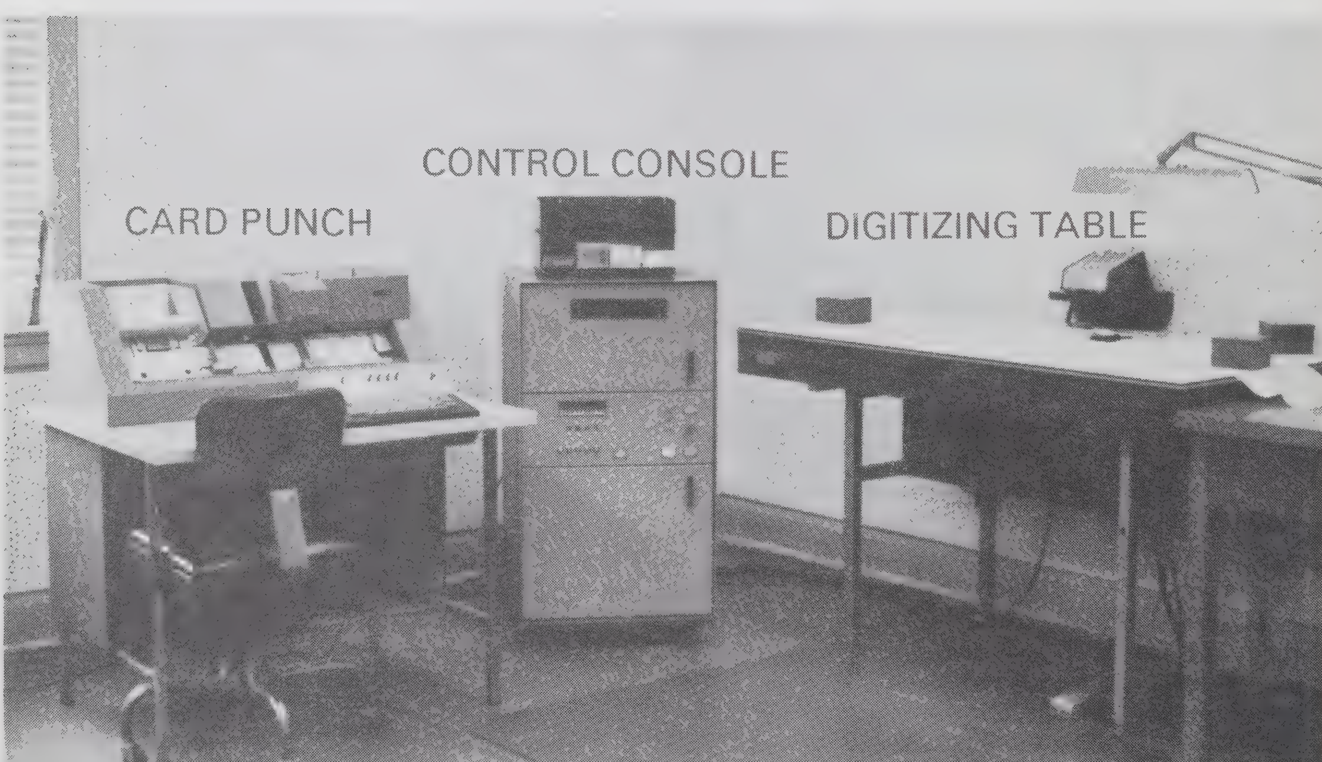

Figure 9. Digitizer installation.

The control console acts as the interface between the digitizing table and the card punch to transfer the information coming from the digitizing table to digital form for the card punch. Two 4-digit visual displays register the X-Y position of the cursor on the table in tenths of millimeters. A 2-inch diameter pointer (or cursor), which is attached to the table by an electrical cord, is used to manually follow the trace on the chart. The working surface of the digitizing table is completely free of mechanisms or overhead arms which could impede ease of operation. A small switch is mounted on the cursor, which when pressed causes the X-Y coordinates of time and stage to be punched onto a card through the control console.

Digitizing consists of an operator manually following the chart trace with the cursor, causing punched cards to be produced; these cards contain X-Y coordinates of each point that is digitized. However, before digitizing can start, the strip charts must be documented. This chart documentation (handwritten notations) consists of recording the station identifier, the gauge reading and time at the start and end of the chart trace as well as identifying any intermediate reference points, such as reversals or clock or pen stoppages; the chart and time scales are also recorded. For digitizing, the chart may be placed on the table at any angle. Six orientation points around the perimeter of the chart are digitized; these points are used later by a computer program to orient the chart and to scale it. Straight-line variable-length segments of the chart trace are digitized. The coordinates are punched at a rate of ¾ of a second per set of coordinates, with a slightly longer pause at the end of each card. The chart documentation information is entered on punched cards either through the card punch or the keyboard on the digitizing table. The time and paper corrections are pro-rated automatically between known checkpoints by the computer program. The rate of processing an ''average'' water level chart having a time scale of 2.4 inches/day is about 3 station-years/day, and includes both chart documentation and digitizing.

The output from the Pencil Follower Unit is punched cards containing the chart documentation and the X-Y coordinates of the end points of straight-line segments of the graph (water level strip chart). The stage-discharge table is entered on punched cards as straight-line segments; the terminal dates of gauge and shift corrections are also entered on punched cards (and distributed on a time basis by the computer program); the stage-discharge table and corrections can usually be entered on some 100 cards. If it is necessary to compute daily discharges manually (e.g. estimated flows), these are entered on punched cards as updating corrections and override the digitized results. Thus, the punched cards containing the digitizer output, the stage-discharge table, and gauge, shift and updating corrections are used as input to a digital computer.

The computer program automatically subdivides the gauge readings to allow for the curvature of the stage-discharge curve. The program computes instantaneous chart readings and applies the necessary time and paper corrections; then the program applies the appropriate gauge and shift corrections after which the mean discharge for the day is computed. The preliminary results are printed showing three months to a page (Fig. 10). A plot of the digitized chart and annual hydrographs of daily stage and daily discharge can also be produced automatically as an option; these can be used as an additional quality check of the equipment and the digitized chart.

A thorough quality check consists of verifying the information entered manually on the keyboard or card punch; also the mean discharge for at least one day per chart segment digitized is computed manually.

Corrections and manually computed daily discharges (updating corrections) are entered on punched cards and another preliminary listing is produced. If the results are believed to be ''final'', an annual page of stage and one for daily discharges (Fig. 10) can be produced along with the annual hydrographs, and also punched cards suitable directly for storage on the main magnetic tape data file (FLOW or LEVELS).

Thus at the District level, the final output from the digitizer system (digital computer) is an annual printout of daily discharges and/or water levels, the annual hydrographs and punched cards suitable directly for processing at Ottawa for the automated publication process and for storage and retrieval of historical data files on magnetic tape.

FINANCIAL CONSIDERATIONS

The capital expenditure for six Pencil Follower systems (Ottawa and five District Offices) would be $150,-000. Assuming the same field installation would be used, the replacement of 800 graph-type recorders with 16-channel PPT (punched paper tape) digital recorders at $700 each, plus 6 translators at $11,000 each, would cost $626,000. Further, it was estimated that about 100 new recorders would be installed annually and since the cost of a digital recorder in 1966 was at least $200 more than a graphical recorder, this would have added $20,000 annually to capital expenditures. It is also likely that both graphical and digital recorders

WATER SURVEY OF CANADA
JUL 24 1973 PAGE 7
OTTAWA, ONT.

LODGE CREEK AT ALBERTA BOUNDARY

STATION NO. 11AB082

PRELIMINARY COMPUTATION SHEET

APR 1965 DAY	G. HT. FEET	DISCHARGE CFS	EQ.G.HT. FEET	MAY 1965 DAY	G. HT. FEET	DISCHARGE CFS	EQ.G.HT. FEET	JUN 1965 DAY	G. HT. FEET	DISCHARGE CFS	EQ.G.HT. FEET
1	-9999.99	-9999.99	-9999.99	1	6.19	309.00	6.20	1	3.62	10.80	3.62
2	-9999.99	-9999.99	-9999.99	2	5.71	228.00	5.72	2	3.60	9.80	3.60
3	-9999.99	-9999.99	-9999.99	3	5.24	155.00	5.24	3	3.55	8.00	3.55
4	-9999.99	-9999.99	-9999.99	4	5.02	123.00	5.03	4	3.52	6.90	3.52
5	-9999.99	-9999.99	-9999.99	5	4.88	106.00	4.87	5	3.51	6.40	3.51
6	-9999.99	-9999.99	-9999.99	6	4.65	83.20	4.65	6	3.49	5.90	3.49
7	2.45	0.00	3.00	7	4.43	62.60	4.43	7	3.48	5.50	3.48
8	2.59	0.00	3.00	8	4.30	51.30	4.30	8	3.46	4.90	3.46
9	2.62	0.00	3.00	9	4.23	45.90	4.23	9	3.47	5.10	3.47
10	2.68	0.00	3.00	10	4.21	44.30	4.21	10	3.43	4.10	3.43
11	2.75	.36	3.18	11	4.12	37.60	4.12	11	3.40	3.30	3.40
12	6.48	421.00	6.79	12	4.11	37.10	4.11	12	3.64	20.40	3.83
13	8.74	896.00	8.77	13	4.14	38.90	4.14	13	4.17	47.30	4.25
14	10.30	1440.00	10.35	14	4.05	33.00	4.05	14	3.79	19.30	3.81
15	11.78	2020.00	11.80	15	3.91	24.80	3.91	15	4.02	31.90	4.03
16	8.70	893.00	8.77	16	3.82	20.00	3.82	16	3.76	17.20	3.77
17	7.01	466.00	7.02	17	3.74	15.80	3.74	17	3.79	18.60	3.79
18	7.18	501.00	7.19	18	3.71	14.50	3.71	18	4.74	101.00	4.83
19	7.66	605.00	7.67	19	3.68	13.20	3.68	19	4.71	89.40	4.71
20	6.95	454.00	6.96	20	3.69	13.80	3.69	20	4.72	90.50	4.72
21	6.17	304.00	6.17	21	3.66	12.20	3.65	21	4.16	41.20	4.17
22	6.99	463.00	7.00	22	3.66	12.20	3.65	22	3.93	25.70	3.93
23	7.51	570.00	7.51	23	3.69	13.90	3.69	23	-9999.99	-9999.99	-9999.99
24	7.48	563.00	7.48	24	3.72	15.10	3.72	24	-9999.99	-9999.99	-9999.99
25	7.74	623.00	7.74	25	3.71	14.80	3.71	25	-9999.99	-9999.99	-9999.99
26	7.95	671.00	7.95	26	3.79	18.40	3.79	26	-9999.99	-9999.99	-9999.99
27	7.50	569.00	7.50	27	3.95	28.30	3.97	27	-9999.99	-9999.99	-9999.99
28	7.00	463.00	7.00	28	4.12	38.20	4.13	28	-9999.99	-9999.99	-9999.99
29	7.09	481.00	7.09	29	3.93	25.90	3.93	29	-9999.99	-9999.99	-9999.99
30	6.98	459.00	6.98	30	3.79	18.40	3.79	30	-9999.99	-9999.99	-9999.99
31	-1111.11	-1111.11	-1111.11	31	3.69	13.90	3.69	31	-1111.11	-1111.11	-1111.11

APR 1965	MAY 1965	JUN 1965
TOTAL = -9999.99	TOTAL = 1668.30	TOTAL = -9999.99
MEAN = -9999.99	MEAN = 53.80	MEAN = -9999.99
AC-FT = -9999.99	AC-FT = 3310.00	AC-FT = -9999.99
MAX. AND MIN. INST. G. HT. AND DISCH.	MAX. AND MIN. INST. G. HT. AND DISCH.	MAX. AND MIN. INST. G. HT. AND DISCH.
12.67 FT AT 435 ON APR 15 1965	6.71 FT AT 0 0 ON MAY 1 1965	5.47 FT AT 937 ON JUN 18 1965
2380.00 CFS AT 435 ON APR 15 1965	405.00 CFS AT 0 0 ON MAY 1 1965	190.00 CFS AT 937 ON JUN 18 1965
2.37 FT AT 0 0 ON APR 7 1965	3.64 FT AT 1222 ON MAY 22 1965	3.36 FT AT 1425 ON JUN 12 1965
0.00 CFS AT 0 0 ON APR 7 1965	11.80 CFS AT 1222 ON MAY 22 1965	2.30 CFS AT 1425 ON JUN 12 1965

NOTE THAT -1111.11 = NOT APPLICABLE, -9999.99 = MISSING DATA

WATER SURVEY OF CANADA
DEC 28 1973 PAGE 7
OTTAWA, ONT.

LODGE CREEK AT ALBERTA BOUNDARY

STATION NO. 11AB082

(PRELIMINARY) DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1965

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	0 B	0 B	0 B	0 B	309	10.8	119	.45	.07	2.7	.30 A	.10 B	1
2	0 B	0 B	0 B	0 B	228	9.8	99.8	.40	.01	2.0	.30 A	.10 B	2
3	0 B	0 B	0 B	0 B	155	8.0	75.9	.37	1.0	2.1	.30 A	.10 B	3
4	0 B	0 B	0 B	0 B	123	6.9	47.5	.40	51.2	1.6	.30 A	.10 B	4
5	0 B	0 B	0 B	0 B	106	6.4	142	.30	13.4	1.2	.30 A	.10 B	5
6	0 B	0 B	0 B	0 B	83.2	5.9	100	.32	3.6	1.5	.30 A	.10 B	6
7	0 B	0 B	0 B	0 B	62.6	5.5	42.2	.30	1.9	1.0	.20 B	.10 B	7
8	0 B	0 B	0 B	0 B	51.3	4.9	48.6	.20	1.0	.65	.20 B	.10 B	8
9	0 B	0 B	0 B	0 B	45.9	5.1	78.6	.20	.45	.50	.20 B	.10 B	9
10	0 B	0 B	0 B	0 B	44.3	4.1	187	.20	.35	.40	.20 B	.10 B	10
11	0 B	0 B	0 B	.15 B	37.6	3.3	64.1	.20	.30	.40	.20 B	.10 B	11
12	0 B	0 B	0 B	300 B	37.1	20.4	41.4	.20	.20	.40	.20 B	.10 B	12
13	0 B	0 B	0 B	896	38.9	47.3	28.2	.10	.20	.40	.20 B	.10 B	13
14	0 B	0 B	0 B	1440	33.0	19.3	19.2	.10	.20	.40	.20 B	.10 B	14
15	0 B	0 B	0 B	2020	24.8	31.9	15.5	.10	.20	.40	.20 B	.10 B	15
16	0 B	0 B	0 B	893	20.0	17.2	14.5 A	.10	.20	.40	.20 B	0 B	16
17	0 B	0 B	0 B	466	15.8	18.6	11.0 E	.10	.20	.40	.20 B	0 B	17
18	0 B	0 B	0 B	501	14.5	101	8.7	.08	.20	.40	.20 B	0 B	18
19	0 B	0 B	0 B	605	13.2	89.4	7.9	.06	.20	.40	.20 B	0 B	19
20	0 B	0 B	0 B	454	13.8	90.5	6.5	.07	.20	.40	.20 B	0 B	20
21	0 B	0 B	0 B	304	12.1 A	41.2	5.8	.04	.17	.40	.20 B	0 B	21
22	0 B	0 B	0 B	463	12.1 A	25.7	4.5	0	.10	.40	.20 B	0 B	22
23	0 B	0 B	0 B	570	13.9	18.1	3.1	0	.06	.40	.20 B	0 B	23
24	0 B	0 B	0 B	563	15.1	13.2	2.8	0	7.0	.40	.20 B	0 B	24
25	0 B	0 B	0 B	623	14.8	758	2.2	0	12.4	.48	.20 B	0 B	25
26	0 B	0 B	0 B	671	18.4	1820	1.8	0	8.4	.42 A	.20 B	0 B	26
27	0 B	0 B	0 B	569	28.3 E	1190	1.5	.01	7.0	.40 A	.10 B	0 B	27
28	0 B	0 B	0 B	463	38.2	627	1.1	.10	5.4	.40 A	.10 B	0 B	28
29	0 B		0 B	481	25.9	244	.95	.10	4.2	.40 A	.10 B	0 B	29
30	0 B		0 B	459	18.4	143	.59	.07	3.4	.40 A	.10 B	0 B	30
31	0 B		0 B		13.9		.50	.08		.40 A		0 B	31
TOTAL	0	0	0	12741.15	1668.1	5386.5	1182.44	4.65	123.21	22.15	6.20	1.50	TOTAL
MEAN	0	0	0	425	53.8	180	38.1	.15	4.1	.71	.21	.05	MEAN
AC-FT	0	0	0	25300	3310	10700	2350	9.2	244	43.9	12.3	3.0	AC-FT
MAX	0	0	0	2020	309	1820	187	.45	51.2	2.7	.30	.10	MAX
MIN	0	0	0	0	12.1	3.3	.50	0	.01	.40	.10	0	MIN

SUMMARY FOR THE YEAR 1965
MEAN DISCHARGE, 57.9 CFS
TOTAL DISCHARGE, 42000 AC-FT
MAXIMUM DAILY DISCHARGE, 2020 CFS ON APR 15
MINIMUM DAILY DISCHARGE, 0 CFS ON JAN 1

A-MANUAL GAUGE
B-ICE CONDITIONS
E-ESTIMATED

MAXIMUM INSTANTANEOUS DISCHARGE, CFS AT ON

Figure 10. Printouts from the STREAM computer program.

would be installed at a digital recorder station for improved reliability and to more easily detect unusual stream conditions, further adding to the cost of a digital recorder system.

Other comparisons of expenditures which were considered were installation and maintenance costs, development of computer programs, computer time for production runs, staff training and other operational costs. Although it is difficult to make reliable comparisons, the digital recorder system would probably be more expensive, especially for maintenance and staff training.

Therefore, it was estimated that by adopting the Pencil Follower (digitizer) system, that there would be an initial ''saving'' in capital expenditures of $500,000 and at least $30,000 annually thereafter.

TECHNICAL CONSIDERATIONS

Technical considerations involved in the digitizer system are as follows:

1. There is considerable interest and advantage in the visual examination and personal interpretation of a graphical record:
   (a) the minor ice jams of a few hours' duration which occur on many streams are readily discernible and, therefore, a correction for backwater effect can be applied,
   (b) in many cases, it is possible to detect the time of ice break-up or the beginning or end of ice effect,
   (c) clock stoppage, plugged intake caused by silting or freezing, float frozen in or resting on the bottom of the well, or slippage of beaded wire (or metal tape) caused by surging are malfunctions or problems common to most installations, whether digital or graphical. However, they produce a characteristic trace on a graphical record which, even if they cannot always be corrected, can at least be recognized; they cannot be easily identified on a punched paper tape record except possibly by examining the holes or the printout or by plotting the stage and/or discharge hydrograph,
   (d) the judgment of the field man is fully exercised in the interpretation of abnormal conditions such as ice jamming, beaver activity, an obstruction on the control (particularly an artificial control), tidal ''blips'', etc.,
   (e) it is possible to identify easily and to assess unusual events such as storms or to supply data for special studies such as ''time-of-travel'' for floods or pollution (low flow), and
   (f) graphical charts can be examined on site and if necessary can be processed manually at remote sites, but digital tapes must be translated and then processed by computer before they can be assessed.
2. The digitizer system can be used for other applications such as stage-discharge curves, flood hydrographs, daily discharge hydrographs, drainage area determination, sediment data computations, river length and determination of latitude and longitude of gauging stations.
3. With the digitizer system, chart corrections are automatic, i.e. no personal interpretation is required for reversal corrections or time and paper corrections. Other types of charts can also be digitized, e.g. curved-line, arc-line or polar.
4. Operator fatigue could be a problem with the digitizer system.
5. The output from most digital recorders is punched paper tape (PPT) on either 5, 8 or 16 channels. The 16-channel tape requires translation to a computer-compatible PPT. Input speeds vary, punched card being the slowest, then PPT and magnetic tape. Since 1965, digital recorders with 5-channel PPT output or with magnetic tape output have been in the research or development stage and problems are still not fully resolved for all-weather or remote field operation.
6. The punch interval for digital recorders is set usually at 15 minutes or 96 readings per day and the mean discharge for the day is the arithmetic mean of the 96 readings. If the number of readings per day were reduced to 24, a significant error could be introduced because the mean for the 24-hour period would be from 12:30 a.m. on that day to 12:30 a.m. of the following day.
7. If the surge is not eliminated, the digital recorder might not record the true mean instantaneous water level at the pre-selected time intervals. It could be argued statistically that they will be averaged over the day because they are random in character. It seems nevertheless that an accurate maximum instantaneous gauge height cannot be known unless the magnitude of the surge is also known, and with digital recorders it is also assumed that the maximum did not occur between punch intervals. Further, if the magnitude of the surge is great, there may be enough slack in the

metal tape (or beaded wire) to allow it to jump off the pulley during the 7 seconds the recorder (hence the pulley) is locked to punch. There is no accurate way of determining when this occurs and the result is a loss of record or an inaccurate record.

8. Certain maintenance problems have been encountered with digital recorder installations:
   (a) battery replacement and cold weather operation,
   (b) clock accuracy not always reliable,
   (c) loss of record may occur because of bent or worn pins. Bent pins sometimes occur on recorders driven by manometers, and
   (d) because of changes caused by humidity, the punched paper tape sometimes cannot be translated (the holes do not match). A partial solution was to use aluminum-backed tapes but this caused the pins to wear rapidly, thus creating punching errors.
9. At some stations, where unusual conditions exist (e.g. "syphoning" over weirs during complete ice cover, extreme shifting of control, ice effect, silting or blockage of the intake pipes) it is probable that graphical recorders would also have to be installed to clarify and resolve the problem.
10. The rate of processing a graphical record is about 3 station-years/day for a 2.4 in./day chart while the translation speed of Digital Recorder 16-channel tapes is about 8 station-years/day for 15-minute punch intervals.
11. An advantage of digital recording over graphical recording is that digital records can be processed almost directly by a computer.
12. The digitizer system is not "computer-bound" — data can still be computed manually from strip charts, but it is unwieldy to do this from PPT. Tentative computations can be performed from strip charts at locations remote from computing centres.
13. Turnaround time between Districts and Data Centres can vary considerably depending on the availability of computing facilities; this could become particularly critical if digital tapes or recorder charts have to be handled by mail. Turnaround time is usually 24 hours or less at the District Offices of the WSC for digitizer applications; at sub-offices, however, turnaround time could be several days or even weeks.
14. Training of personnel is an important factor in any automated process. Field personnel would require training in the operation and maintenance of digital equipment but no new training would be required if graphical recorders were retained. Field procedures would in fact be simplified because charts would not have to be reset for time or stage as frequently, since these corrections are made automatically by the computer program.

REASONS FOR SELECTION OF DIGITIZER SYSTEM

The following are the main factors which led to the decision to adopt the Digitizer System as the standard for hydrometric computations in the Water Survey of Canada:

1. A digital record provides less information (fewer water level observations) than a graphical record because of its inherent discontinuity.

2. Over the years, graphical recorders have proven to be quite reliable for providing a continuous water level record with acceptable accuracy for use in streamflow computations. Although the digital recorder is potentially a reliable instrument for recording water levels under adverse field conditions, it was still in the development and experimental stage in 1965-66.

3. Using a digital recorder, the reliability of the water level data cannot be assessed without first being processed by a digital computer. This could mean unacceptable delays in turnaround of possibly several weeks.

4. The versatility of the digitizer system is important in that other types of data can be processed, e.g. drainage area, river length, location of gauging station (latitude — longitude), stage-discharge curves.

5. Although the technical advantages were considered to be more important, financial advantages alone would have justified the selection of the digitizer system over the digital recorder system.

DATA STORAGE AND RETRIEVAL SYSTEM

Early in 1966, potential users were canvassed for opinions and suggestions on what types of data should be stored and what types of retrieval were desired. Preliminary considerations included the storage of daily discharges, daily water levels, instantaneous maximum,

discharge measurement results, reservoir capacity, stations affected by tides (daily maximum and minimum), descriptive information about gauging stations, such as latitude and longitude, drainage area, etc.

In 1966, a pilot project was undertaken to evaluate procedures for assembling data for keypunching and for storage and retrieval of data. Although some indications of possible problem areas were revealed, the project was undertaken too hurriedly, and as a result some of the computer programs were inefficient and were later modified or re-written.

The following are the main factors that dictated the design of the data files:

1. The main file (FLOW) is to be arranged so that the entire period of record of any given station is found on a single reel of tape.
2. Although the main file would be located in Ottawa, the Districts would still be responsible for the data stored on magnetic tape by verifying printouts of daily discharges. These printouts would become the official records, replacing the variety of forms previously used.
3. Data stored at Ottawa would be supplied to users on punched cards, magnetic tape or printouts. Initially, retrieval would not include statistical analysis of data but this should be considered for the future.

PROBLEMS AND LIMITATIONS IN COMPUTER SERVICES

Certain problems and limitations in computer services must be considered:

1. Computer programming is the most critical and the most important factor in the design, development and implementation of both the data storage and retrieval system and the digitizer system.
2. During the development stage from 1965 to 1967, the Computer Science Division of the Department of Energy, Mines and Resources (EMR) provided consultant services on the design of the data processing system, but they could not provide programming assistance.
3. In later stages, some of the programming was done under contract with consultants or by staff of the Computer Science Division. This practice, however, is not recommended unless the project can be identified precisely and described in detail, and unless staff are available for discussion and monitoring. Consultants or outside programmers are unfamiliar with hydrometric work, and instructions and requirements are often not clearly communicated.
4. Although computing services were provided free of charge by EMR on their CDC 3100 computer, certain restrictions were imposed when using it:
   (a) 556 bpi,
   (b) magnetic tape (disk not available),
   (c) BCD not binary (BCD more compatible with other computers), and
   (d) FORTRAN (COBOL Compiler was not available at EMR and PL/1 was not permitted).
5. Program development for the digitizer application for streamflow computations was carried out on the UNIVAC 1108 through a terminal at EMR because the CDC 3100 did not have sufficient memory.
6. Turnaround time for program testing was erratic because of frequent machine breakdowns or other delays, resulting in about 3 runs/week during the early stages of development.
7. Keypunching services were often slow.
8. During conversion from the CDC 3100 to the CDC 6400 in 1971, staff were not available for program development.
9. During 1967, keypunching of data under contract and computer programming to store and retrieve these data were conducted simultaneously. Delivery service was at times either nonexistent or so slow that programmers had to perform these duties also. Computers at other data centres (IBM 1401 and IBM 7074) were used for card processing and for producing printouts suitable for the initial visual verification of data by the Districts.

Automated Hydrometric Computations

COMPUTATION PROCEDURES

Prior to the introduction of the digitizer system, all hydrometric data were computed manually according to standardized procedures. These procedures will continue to be used because computation of data for some stations may never be fully automated. Manual procedures will still be required also for tentative computations and for spot checking automated computations.

There is no basic change in the method of collecting field data. Certain parts of the office computations are common to both manual and automated procedures: discharge measurement results are tabulated and plotted; stage-discharge curves are drawn by hand, and stage-discharge tables produced manually; some daily discharges, such as those during ice conditions, extreme shifting control conditions or periods of missing gauge height record (estimates) are computed manually because personal interpretation is required. Automation of the following operations, however, has substantially reduced computation time:

1. Determination of the mean gauge readings from the recorder charts (Fig. 7) and, where necessary, subdivision to compensate for the curvature of the stage-discharge curve.
2. Time distribution of gauge and shift corrections.
3. Application of corrections and stage-discharge tables to graphical water level charts to give daily mean water levels and daily discharges.
4. Plotting of annual stage or discharge hydrograph.
5. Computation of monthly and annual summary data.
6. Compilation and computation of historical summary data such as monthly and annual mean discharges for the period of record.

TYPES OF DIGITIZER APPLICATIONS

The different types of digitizer applications are listed below:

1. STREAM — computes daily discharges and/or water levels (Fig. 10) from cards resulting from digitized strip charts. The STREAM program is split into two parts (TRIPLE and ANNUAL) at computing centres where insufficient core storage is available. Output options consist of a plot of the digitized points, annual hydrographs or punched cards suitable directly for storage on the FLOW or LEVELS files. The basic STREAM computer program has been modified for the following applications:

   (a) HOURLY — computes instantaneous hourly water levels and/or discharges using the same digitizer cards as obtained for the STREAM program,

   (b) TIDAL — this is a modification of the HOURLY program and differs mainly in the format of the station identifier and output listing, and

   (c) SEDCON — computes daily suspended sediment concentration from graphs drawn by hand. An output option will produce punched cards suitable directly for storage on the SUSCON file of daily suspended sediment loads.

2. AREA — computes drainage area from maps.
3. Other applications partly operational or in the development stage are:

   (a) POINT — determines latitude and longitude of digitized points or locations on a map,

   (b) CURVE — produces card output of digitized stage-discharge curves suitable for the STREAM program,

   (c) LENGTH — computes river length from maps, and

   (d) TICON — computes hourly suspended sediment concentration.

RELATED COMPUTER PROGRAMS

Other related computer programs are:

1. MANUAL — computes daily discharges and/or

water levels for stations equipped with a manual gauge only. Output options are the same as for STREAM; card decks for the stage-discharge table and correction tables are interchangeable with STREAM.

2. SAVE — used for storage and retrieval of digitized cards from STREAM, AREA, etc. using magnetic tape, thus eliminating the need for permanent storage of punched cards.

3. TONS — computes the suspended sediment load in tons/day, using daily data as stored on the FLOW and SUSCON files. This is combined with descriptive information from the HYDEX file to produce computer printouts showing daily and monthly discharge in cfs, daily suspended sediment load in grams/liter and total daily and monthly suspended sediment in tons/day, with 3 months of data per page.

4. Other computer programs in the development stage are:

   (a) GCSC — computes daily gauge and/or shift corrections from field observations and produces an annual page showing these corrections, which can then be used in manual computations or when making quality checks of the output from the STREAM or MANUAL programs, and

   (b) SAM — computes the peak discharge from observed field data, e.g. water slope, cross-sectional area and roughness coefficient.

IMPLEMENTATION IN DISTRICTS

The first digitizer unit was installed in Ottawa in 1966 to develop procedures and computer programs.

In 1967, a digitizer unit was installed in Calgary and after some initial implementation problems, mainly with the equipment, the system became operational in 1968.

In 1968, digitizer units were installed in Guelph, Halifax, Winnipeg and Vancouver and systems were operational in 1969.

In 1969, a digitizer unit was installed in Regina and was operational in 1970.

In 1974, the digitizer unit originally installed in Ottawa was moved to Montreal and a new Gradicon digitizer/Univac 1710 buffered card punch was installed in Ottawa.

One of the major problems was in the delivery of card punches (up to 9 months from acceptance of con-

Contracts for Computer Use

CITY	COMPUTER	AGENCY
Vancouver	IBM 360/67	University of British Columbia
Calgary	CDC3300 (split program)	Computer Data Processors Ltd.
	CDC 6400	University of Calgary
Regina	IBM 360/50 (split program)	Sask. Govt. Systems Centre
Winnipeg	IBM 360/65	University of Manitoba
	UNIVAC 1108 (from terminal to Calgary)	Computing Services Canada Ltd.
Guelph	IBM 360/65	University of Guelph
Halifax	CDC 3150 (split program)	Bedford Institute of Oceanography (no charge)
Montreal	UNIVAC 1108 (from terminal to Ottawa)	Computel Systems Ltd.
Ottawa	CDC 6400	Energy, Mines and Resources
	IBM 360/85	Systems Dimensions Ltd.
	UNIVAC 1108, IBM 370/65	Computel Systems Ltd.
	IBM 360/65	Computer Services Bureau.

tracts) and their interfacing with the digitizing table.

An important feature of this system is that specially-trained operators are not required. Training of personnel was conducted in two stages, one week in Ottawa for two people from each District, then a follow-up training period of 2 weeks for implementation at computer centres at the Districts, after installation had been completed. Annual visits are made for two to three days to discuss problems and/or implement newly-developed applications or modifications.

After warranty periods had expired, service maintenance contracts were obtained at an annual cost of about 11% of the capital expenditure.

Computer programs had to be modified for some computers because of insufficient memory or restrictions imposed by computing centres. Costs vary considerably from centre to centre, but an average cost to produce one year of data is about $30 (publication costs are additional). Contracts for computer use at the Districts and at Ottawa are presently held with the agencies listed in the table on page 15.

The STREAM computer program has also been implemented and is operational for the Ontario Ministry of the Environment (IBM 360/65 at Toronto).

Storage and Retrieval of Data

GENERAL DESCRIPTION OF DATA PROCESSING SYSTEM

Figure 11 is a general system flowchart for data files.

When the CDC 3100 computer was used, data were stored on magnetic tape on 7-track BCD (even parity) at a density of 556 bpi. When the CDC 3100 was replaced by the CDC 6400 in October 1971, data were still stored on magnetic tape on 7-track BCD (even parity) but at a density of 800 bpi.

Records on any one reel are fixed length. Record sizes of 60, 80, 132 and 300 characters are used, with a blocking factor of 5 or 10. For example, the FLOW file has 300-character records with a blocking factor of 5. Tapes produced for direct printing have 132-character records with a blocking factor of 10. Tapes resulting from the card to tape operation have 80-character records with a blocking factor of 10. "Tape Header" and "Trailer" records are used on all tapes except those containing retrieved data. All tapes except print files (132-character records) have an "End-of-File" record just ahead of the "Trailer" record. All blocked tapes contain "Padding" records. The last block on tape is followed by a tape mark. Some 400 magnetic tapes (including at least three generations of backup tapes) are now in use to handle the various data files at the Computer Science Centre, Department of Energy, Mines and Resources.

The data are forwarded annually to Ottawa by the Districts either on computation forms or punched cards, but usually on magnetic tape. The data are usually stored by District and by station number within the District. After verification of printouts has been completed by the Districts, the data are re-arranged by province or region and manuscripts are submitted for publication by an automated technique described later.

The current year's data are then merged with the historical data so that data for the period of record for any one station are available on one tape. Streamflow data can now be supplied to users in the output of their choice, i.e. on punched cards, printouts or magnetic tape.

Computer programs for the storage and retrieval of data are written by Branch staff. Instruction manuals and program documentation are completed as time permits, but there is a need to concentrate more on this because of time lost during conversion from one computer to another and also because staff turnover creates problems of continuity.

SOURCE DOCUMENTS

When the decision to automate historical hydrometric data was made, several alternatives were possible as to the type of source document that should be given to keypunch operators. The alternatives were:

1. Original records on forms R43, R79 or equivalent.
2. Copies of original records.
3. Published records.
4. Data copied by hand on coding sheets.

The use of original records was unsatisfactory because of the excessive marking-up involved. Copying data onto coding sheets is time-consuming. It was decided, therefore, to use the annual publications as the major type of source document; for unpublished data, copies of original forms were used. Corrections to both types of source document were submitted on coding sheets.

Preparation of source documents for keypunching was started in December 1966. The contract stipulated that keypunching was to begin in May 1967 and was to be completed by October 1967. Since data were recorded on a variety of forms (these forms also included other types of data such as daily gauge heights and descriptive information), they had to be precisely edited by hand so that the keypunch operators would know what data were to be keypunched. This preparation was done mostly by District staff in accordance with standard procedures developed at Ottawa in consultation with the Computer Science Centre (EMR) and IBM personnel. The pages from 2 sets of publications were separated, and copies of original records for unpublished data were made. These data were then assembled by station number and by District. Considerable manual editing was

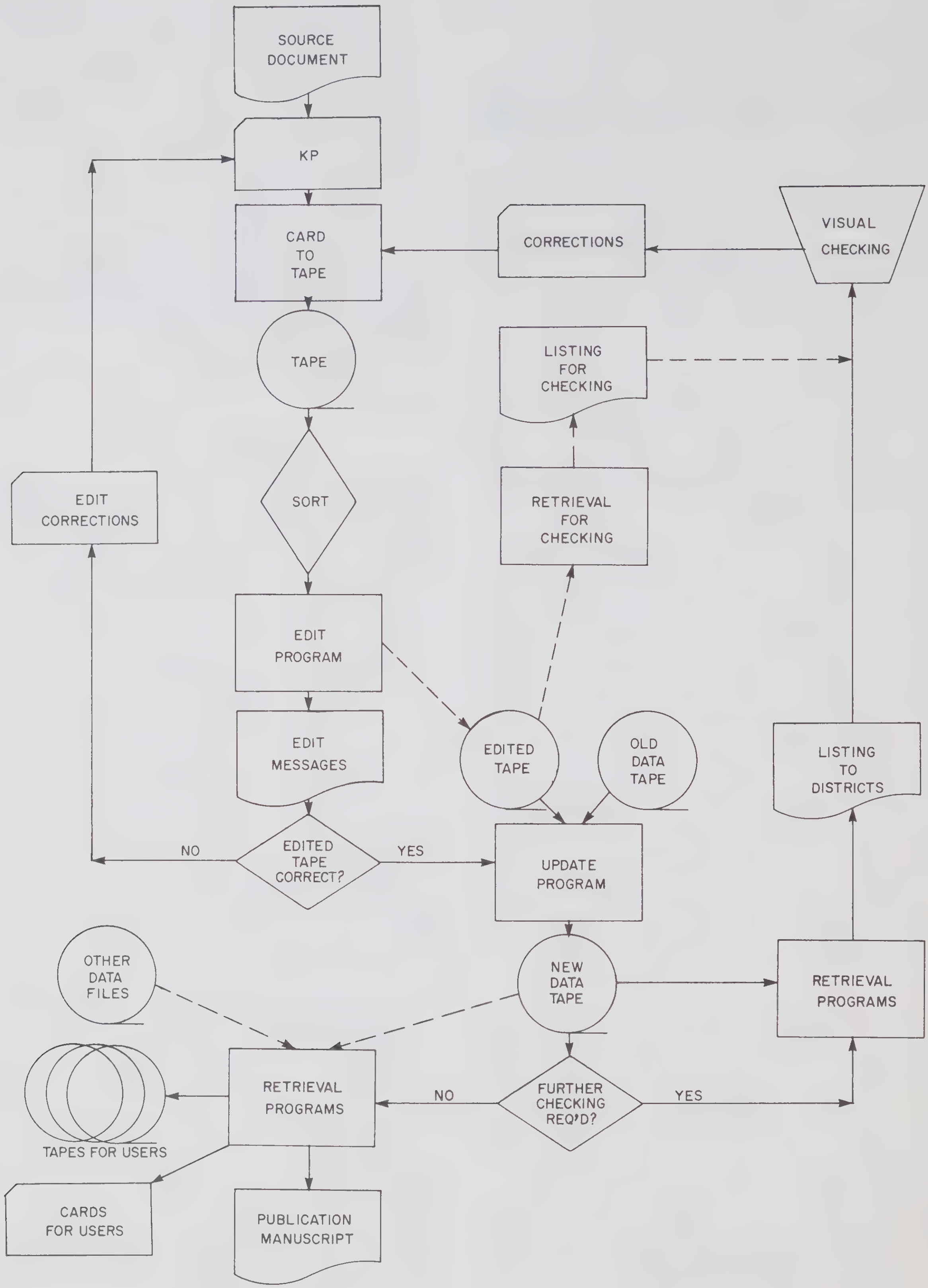

Figure 11. General system flowchart for data files.

required to delete data and information not required for keypunching. Some of the factors involved were: (a) the need to identify symbols for discharges where a variety of letters had been used, making necessary the use of colour codes; and (b) the use of a variety of forms as source documents and the fact that the information presented on these forms was not always clear. About 3 man-years were required to prepare source documents for keypunching.

KEYPUNCHING

In 1966, a contract was awarded to keypunch and keyverify the daily discharge data during the 1967-68 fiscal year. The data were keypunched in "free-form" — the format was developed after consultation with the Computer Science Division (EMR) and the Keypunching Contractor (IBM). This was completed on schedule at a cost of about $80,000 with 10 to 20 operators working for 2 shifts/day from April to October 1967. Over one million cards were produced; these were destroyed in 1970 after the data had been converted to magnetic tape and verified by the Districts. This included daily discharge data to 1966. In the subsequent 2 to 3 years, daily discharges for 1967 to 1969 were keypunched from computation forms by the Computer Science Centre (EMR). Over 75% of the daily discharges and water levels are now obtained directly as card output from the STREAM and MANUAL computer programs. Some of the problems were: (a) keypunch operators complained that the printing in the data publications was too small, thus difficult to read; copies of some forms were unclear, especially decimal points; and (b) delivery service was at times either non-existent or unreliable, resulting in programmers or technicians having to pick up and deliver punched cards for processing.

During the 1968-69 fiscal year, the OCR method (Optical Character Recognition) was used for some daily discharges and for the historical LEVELS files at the request of the Computer Science Centre (EMR). Briefly, this method consists of typing the data in a special format. The typed page was then scanned electronically by a Page Reader and converted to magnetic tape. This procedure is not recommended because of the problems experienced in obtaining data free of typing errors — data are verified by a visual check of the typing and not by keyverifying, thus many errors were found when the listings were checked against the original documents.

SIGNIFICANT FIGURES AND SYMBOLS

Throughout the history of the Water Survey of Canada many rules for significant figures were used — rules that were sometimes inconsistent even between Districts for the same year. In some years, data were expressed to 2 significant figures and in others to 4 or more. The method of computing the acre-foot figure also varied — in some years it was computed from the monthly total and in others from the monthly mean. In many years, published daily discharge data were, for example, shown as 124.00 instead of 124 because the flow for another day in the month was 1.19 cfs (two decimal places) and typesetting rules for publication at that time required the same number of decimal places for all figures in the same month. Further, many discharge figures were originally computed and published to fewer significant figures than presently used or were rounded to the nearest 5.

Daily discharge data were keypunched as originally computed or published and rounded later according to the present rule for significant figures. Daily figures computed to fewer significant figures than now used were not re-calculated. Figures between 50 and 100, however, can be stored and retrieved to two significant figures, e.g. 52 (not 52.0).

A very complex system would be required if significant figures were to reflect the accuracy of the data not only within a particular year but from year to year. It was decided, therefore, that all data generated from the summation of the daily values would be expressed to three significant figures above 10, to the nearest tenth from 1 to 10 and to the nearest hundredth below 1. Monthly totals are not rounded. Values below 0.005 are shown as "0". The last significant figure is rounded up if the following digit is exactly 5, e.g. 5285 is rounded to 5290.

Over the years, various symbols were used to explain certain conditions such as ice effect, estimated data, pools, shifting control, etc. Further, different letters were used to identify the same condition, or the same letter to identify different conditions, although this was generally explained in a footnote. In recent years, the symbol "t" was used to indicate a flow between 0.05 cfs (a "trickle") and "nil", but in earlier years it was used to indicate that an automatic recording gauge was used. Some Districts recorded "0", "0.0" or "nil" to indicate that a stream was "dry" while others showed the same thing to indicate a "trickle" (without a symbol). Therefore, the flow below 0.005 cfs (including "no flow" or "nil") is now shown as "0". If such a condition is critical to a specific study, the user must consult the District Office.

It was decided to use the following three standard symbols for the period of record for daily discharges: A, Manual gauge; B, Ice conditions; E, Estimated. However, no symbols would be used for any generated data such as monthly means, ac-ft, etc.

VERIFICATION OF STORED DATA

The original system for the storage and retrieval of streamflow data made use of three computers. The data on cards were converted to magnetic tape on an IBM 1401, sorted on an IBM 7074 (both computers were with the Department of National Revenue) and edited on a CDC 3100 at EMR. The edited tape was then used to produce preliminary listings of daily data and monthly summaries on an IBM 1401.

These daily discharge listings were sent to the Districts for verification of the monthly totals against the original documents. Daily values were checked where monthly totals were not available; all symbols (A, B and E) were checked against original records. Corrections were sent to Ottawa on coding sheets, updated and the procedure repeated until final verification of historical daily discharge data had been achieved.

The historical water level data prior to 1969 have not yet been completely verified.

Some types of errors found were: (a) keypunching errors; (b) missing data, e.g. May 31 value; (c) typographical errors; (d) wrong monthly totals, hence incorrect summary data; and (e) wrong station number.

Final listings showing station name and number, daily discharge data rounded to a standard rule for the period of record (and lined up), summary for the year or period, and symbols, were sent to the Districts to be used as the official documents, replacing the variety of other forms. The "other" forms, however, will not be destroyed as they contain related hydrometric data or information, such as daily gauge heights, distribution of shift corrections, explanation of revisions, description of special computations and explanatory notes on unusual conditions.

TYPE AND SIZE OF DATA FILES

The type and size of data files used are described here:

1. FLOW file — consists of 15 tapes which contain about 34,000 station-years of daily discharge data to 1972 for all the Districts. One month of record is 300 characters long and is blocked five. Thus at 800 bpi, one station-year of data is stored on about 5 inches of magnetic tape, including a ¾ inch inter-record gap, this is about 5000 station-years per 2400—ft tape, or a total of about 125,000,000 characters. This file is fully operational.
2. HYDEX file — consists of one tape for some 2500 active stations (including some 200 stations for which data are contributed) and 2300 discontinued stations, and contains descriptive information extracted from Gauging Station Inventory Form IW-2006 (R285), e.g. station no., name, drainage area, latitude and longitude, period of record, regulated or natural flow. This file is fully operational, although it is often modified as new requirements occur.
3. LEVELS file — consists of 7 tapes, one for each District, which at present contain about 7,000 station-years of daily water levels for selected stations. Data verification is underway and additional data are still being submitted. This file is operational only for data from 1969 to 1972.
4. PEAKS file — consists of one tape for all stations for all the Districts and contains annual maximum instantaneous discharges and water levels for the period of record. This file is operational for the Annual and Summary publications, and programs are being developed to supply data to users on punched cards or magnetic tape.
5. RESVOR file — consists of one tape for some 30 stations for two Districts and contains stage-capacity tables for reservoirs. This file is partly operational; major modifications in file design and programming are required before it can be considered complete.
6. SUSCON file — consists of one tape for all stations for all Districts and contains some 400 station-years of historical daily suspended sediment concentration to 1969. This file is partly operational, although listings of daily discharges, suspended sediment concentration and tons/day are produced for use in data publications.

SUPPLYING DATA TO USERS

Data publications and/or daily discharge data on magnetic tape are supplied to about 18 foreign countries, and in Canada to engineering consultants, universities (libraries, professors and students), provincial agencies (water resources, power, highways and fisheries), federal departments, municipal agencies (waterworks), power companies, railway companies, and private individuals.

A booklet containing a description of the card and tape formats for supplying data to users is available. This booklet as well as the data publications may be obtained upon application to the Director, Water Resources Branch, Department of the Environment, Ottawa, Ontario, K1A 0E7.

Automated Publication Techniques

HISTORY OF PUBLICATIONS

Surface water data were first published in 1908 and included streamflow and water level (hydrometric) data for Alberta and Saskatchewan. Data for southern British Columbia were first published in 1911, for Manitoba in 1912 and eastern Canada in 1918. Over the years to date, data have been presented in some 200 publications in various formats and for various combinations of provinces and regions, either annually or biennially. Some daily discharge data have never been published nor have related data such as the elements of discharge measurements (area, velocity, ice thickness, etc.) or daily water levels if daily discharges were computed.

Data were computed and published on a calendar-year basis up to 1917, on a water-year basis (October 1 to September 30) from 1918-67, and on a calendar-year basis from 1968 to date. It was decided to adopt the calendar-year basis because the water year does not represent a complete hydrologic cycle for many regions in Canada. In addition, other types of water data are compiled on a calendar-year basis and since data are now stored on magnetic tape, any desired ''year'' can be retrieved.

Prior to about 1950, data submitted by the Districts in handwritten or typed form were typeset and printed by the letterpress process. After 1950, to save time, the data submitted were re-typed by electric typewriter on standard master sheets and printed at reduced size by photo-offset lithography. Since 1969, data have been submitted on punched cards or magnetic tape. The original intention was to use high-quality computer printouts as copy for printing, but this was changed to take advantage of the higher-quality photocomposition output of the Alphatext-Alphanumeric system.

PREPARATION OF COPY FOR PRINTING

Many different systems of copy preparation are in use at the present time, and the method used in a particular case is the one which will produce a printed book with the least cost and greatest saving in time. The printing process used for WSC publications is photo-offset lithography and the copy provided for this type of printing can be produced by a number of different methods, the most practicable of which for WSC purposes are typescript, computer printout, and Alphanumeric photocomposition.

Typescript

Electric typewriters can produce high-quality copy suitable for photography. The main disadvantage with this system is the lack of a retention (memory) facility.

Computer Printout

Output from the Alphatext System may be obtained in the form of a computer printout with a typescript standard. In this case the input material is stored in the memory of the computer and for publications such as instruction manuals which are updated periodically but where high-quality photocomposed type is not essential, a typescript computer printer is completely satisfactory.

Alphanumeric Photocomposition

Alphanumeric photocomposition is the end product of the Alphatext system and is a highly-sophisticated method of producing photo-type from the manuscript or data material stored in the system.

A cathode ray tube (CRT) printer operates as a high-speed output device (6 seconds/page) with an IBM 360 computer, exposing character images onto photosensitive paper. In the case of material for data publications, the system is programmed to produce finished camera-ready pages suitable for photo-offset lithography.

Input to the system is by special typewriter terminal in the Publications Office in Ottawa or as line images on a 1600 bpi magnetic tape (identical to computer printouts). The cost of photocomposition is about $2 to $3 per page (two stations per page) for data submitted as line images on magnetic tape (uniform type fonts) and up to $10 per page for data that may require special program instructions to accommodate a number of different type fonts.

The main advantage in entering text material through a terminal to a computer is that once it has been proofread, only the changes or additions have to be typed. Magnetic tapes containing numeric data are ini-

tially produced at 800 bpi on the CDC 6400 and converted to 1600 bpi on an IBM 360 for input to the Alphatext system.

The turnaround time for this service is less than 24 hours if numeric data are submitted on 1600 bpi magnetic tape and 2 to 3 days if entered as text material through a terminal (after initial preparation). Thus it is virtually impossible to improve significantly on this phase of the publication process.

PREPARATION OF MANUSCRIPT FOR ALPHANUMERIC PHOTOCOMPOSITION

An inventory form IW-2006 (R285), showing descriptive information on each gauging station, is kept up to date by the Districts and this information is stored on the HYDEX magnetic tape file at Ottawa. A magnetic tape is produced containing only those stations to be published for that year. Listings of these stations are forwarded to the Districts prior to submission of data for publication in the event that the inventory forms have been changed in the interim.

Daily discharges and water levels are computed by the Districts using the STREAM (digitizer) or MANUAL computer programs, the output being punched cards in a format suitable for storage on the FLOW and LEVELS files; data are computed also by hand and the daily discharges and water levels are keypunched in the same format as the STREAM and MANUAL output cards. These daily discharges and water levels are converted from cards to magnetic tape at the District Computing Centre and the tape sent to Ottawa. The tapes from all the Districts are sorted and combined on one FLOW tape and one LEVELS tape for the year for which data are to be published.

Where applicable, a maximum instantaneous discharge or water level for the year is submitted by the Districts on cards or coding forms and stored on the one PEAKS magnetic tape file at Ottawa. Also identified are those stations for which there is a valid annual extreme of daily discharge or water level for an incomplete year of data.

Using the four magnetic tape files (HYDEX, FLOW, LEVELS and PEAKS), printouts showing data exactly as they will be published are sent to the Districts by Air Express for verification. Extensive corrections are returned by Air Express but minor changes are made by telephone.

Once verified, the four magnetic tape files are sorted and combined by various computer programs using the CDC 6400 so that data are retrieved as line images (the same as the printouts) by province or region (one tape for each publication). Two station-years of data are shown on one page, the page numbers are entered automatically, and an index of gauging stations is also prepared automatically. These tapes are changed from BCD at 800 bpi (CDC 6400) to EBCDIC at 1600 bpi on an IBM 360 and sent to Alphatext Systems Limited to produce the 8 1/2'' x 11'' pages which will be used for printing.

While the data tapes are being prepared, introductory text material is entered into the Alphatext system via the terminal in the Publications Office and photo-ready copies produced using special coding instructions to give the desired photocomposed format. Once the original text of the introductory material has been entered, only the changes or additions have to be entered for subsequent years. The introductory material and data pages are now ready for printing.

At present, the automated procedure is used only for annual Surface Water Data publications and for Historical Streamflow Summary publications. Development of an automated procedure for the Surface Water Data Reference Index and Sediment Data publications was started in 1973.

PRINTING

Normal printing time for data publications under a pre-arranged contract is from 18 to 24 working days. Proofs are submitted in approximately 6 days from receipt of camera-ready copy, and finished publications from 12 to 18 days from return of proofs. Allowing for checking of proofs and transportation time for proofs and finished publications, the total elapsed time from submission of camera-ready copy for printing to delivery of finished books is about six weeks, compared to from three to nine months under the previous system.

Assuming four to six weeks for computer processing in Ottawa, verification by the Districts, and packaging and mailing, data in published form should be available to the user not later than three months from the date of submission of the magnetic tape to Ottawa by the Districts.

Data Publications

Surface Water Data Reference Index

This publication contains a reference to available data and is published annually in one volume for Canada (Fig. 12). Gauging stations are listed by province or territory in an upstream to downstream order. Coloured hydrometric maps to a scale of 1'' = 32 miles, showing the locations of both active and discontinued stations, were distributed in 1973 as a supplement to the 1972 annual publication.

Surface Water Data

This publication contains tabulations of daily discharges and water levels on a calendar-year basis, with stations listed alphabetically (Fig. 13). These data are published annually in seven volumes, by province or region, for British Columbia, Alberta, Saskatchewan, Manitoba, Yukon Territory and Northwest Territories, Ontario (includes stations operated in Quebec by the Water Survey of Canada), and the Atlantic Provinces.

Historical Streamflow Summary

This publication contains tabulations of historical monthly and annual mean discharges, annual maximum and minimum daily discharges and annual maximum instantaneous discharges, for all stations for which five or more years of streamflow data have been collected (Fig. 14). These data are published in seven volumes by province or region; stations are listed alphabetically, as in the annual Surface Water Data publications. The first edition of these publications included streamflow data to 1970. Format changes are planned for the next edition which will probably be published in 1974 and will include historical streamflow data to 1973 for all stations, regardless of the period of record.

Sediment Data

This publication contains tabulations of daily suspended sediment discharges and particle-size distribution of suspended sediment, bed load and bed material (Fig. 15). These data are published annually in one volume for Canada with stations listed alphabetically by province.

Station No.	Name	Drainage Area (Sq. Mi.)	Gauge Location	Discharge Records . (Stage Only *) (Misc. Meas. #)	Type of Gauge	Oper-ation	Mag-netic Tape	Note
	. . Red River:							
05MH005	. . . Assiniboine River near Holland	61,300	49° 41' 54" 98° 53' 56"	54-60* 61-66 67-72	M M R	S S C	Yes	1
05MJ005	. . . Assiniboine River near Rossendale	61,400	49° 45' 32" 98° 38' 32" W21-09-09-W1	70-72	M	C	Yes	1
05MJ006	. . . Portage Reservoir near Portage La Prairie		49° 56' 10" 98° 20' 10" SE22-11-07-W1	70-72*	R	S	No	5
05MJ003	. . . Assiniboine River near Portage La Prairie	61,400	49° 56' 09" 98° 16' 48" SW19-11-06-W1	22*,31*,23-30 52-60 61-72	M M R	S C C	Yes	1,2,6
05MJ001	. . . Assiniboine River at Headingley	61,800	49° 52' 09" 97° 24' 10"	13-52 53-72	M R	C C	Yes	1,5,6
05MJ002	. . . Assiniboine River at St. James		49° 52' 30" 97° 11' 30"	12-13 34#, 37#	M -	S -	Yes	
05MD007	. . . . Shell River near Roblin	543	51° 21' 39" 101° 15' 21" SW06-28-27-W1	62-72	M	C	Yes	
05MD002	. . . . Shell River Four Miles South of Roblin	712	51° 10' 10" 101° 19' 40"	19-20#, 33-35# 22-27 28-32	- M M	- C S	Yes	
05MD001	. . . . Shell River at Asessippi		50° 56' 50" 101° 19' 00"	13#, 24# 14-19 20, 21	- M M	- C S	Yes	
05MD005	. . . . Shell River near Inglis	779	50° 57' 40" 101° 19' 05" NW03-23-28-W1	48-55 56-61 62-72	M M R	S C C	Yes	
	. . . . . East Shell River:							
05MD008	. . . . . . Childs Lake near Boggy Creek		51° 34' 37" 101° 01' 54"	64-72*	M	S	No	
05ME005	. . . . Conjuring Creek near Russell	33.0	50° 47' 30" 101° 17' 55" NE09-21-28-W1	59-72	M	S	Yes	
05JM016	. . . . Qu'Appelle River near St. Lazare	22,000	50° 26' 25" 101° 19' 35"	67-72	M	C	No	2,4
05ME003	. . . . Birdtail Creek near Birtle	423	50° 31' 50" 100° 57' 00"	53-72	M	S	Yes	
05ME002	. . . . Birdtail Creek at Birtle		50° 25' 15" 101° 02' 40"	14-17 24-26, 28 27*	M M M	C S S	Yes	3

M - Manual gauge
R - Recording gauge
C - Continuous operation
S - Seasonal operation

1 - Sediment data available.
2 - Water quality data available.
3 - Miscellaneous measurements were obtained in 1918 and 1921.
4 - Data not published.
5 - Telemetering device installed.
6 - Data to 1960 have been reviewed.

Figure 12. Sample page from "Surface Water Data Reference Index" Publication.

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VEDDER RIVER NEAR YARROW - STATION NO. 08MH047

DAILY WATER LEVEL IN FEET FOR 1972

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	8.52	8.71	10.29	9.57	9.44	12.76	12.09	11.30	9.73	9.79	8.82	9.14	1
2	8.54	8.65	10.10	9.87	9.45	12.44	11.95	11.16	9.64	9.90	9.45	9.52	2
3	8.44	8.59	9.89	9.77	9.54	12.36	11.97	11.10	9.62	9.90	9.43	9.13	3
4	8.54	8.57	9.72	9.79	9.70	12.35	12.12	11.08	9.61	9.79	9.78	9.70	4
5	8.44	8.56	10.79	10.72	10.04	12.39	12.31	11.05	9.61	9.63	9.92	9.64	5
6	8.46	8.57	11.79	10.97	10.54	12.55	12.51	11.01	9.55	9.54	9.45	9.68	6
7	8.47	8.86	10.77	10.49	10.49	12.87	12.52	11.05	9.47	9.51	9.56	9.79	7
8	8.44	8.83	10.45	10.42	10.56	13.00	12.09	11.13	9.43	9.50	9.52	9.43	8
9	8.44	8.85	10.28	10.22	10.76	13.38	11.86	11.20	9.73	9.52	9.46	8.98	9
10	8.46	8.68	11.22	10.07	10.57	13.39	11.60	10.97	9.57	9.53	9.44	8.94	10
11	8.54	8.78	11.47	9.97	10.44	13.19	11.42	10.76	9.54	9.42	9.36	8.80	11
12	8.56	8.78	11.25	9.87	10.54	12.88	13.10	10.55	9.38	9.35	9.26	8.76	12
13	8.48	9.59	11.62	9.74	11.38	12.38	13.64	10.26	9.34	9.34	9.23	8.76	13
14	8.45	9.12	11.64	9.66	12.06	12.05	12.66	10.25	9.31	9.25	9.17	8.75	14
15	8.42	9.15	11.27	9.76	12.29	11.97	12.36	10.20	9.30	9.18	9.12	8.69	15
16	8.59	11.01	11.67	9.65	12.39	12.21	12.50	10.33	9.25	9.16	9.07	9.02	16
17	8.48	10.57	12.09	9.55	12.09	11.98	12.41	10.30	9.31	9.11	9.04	9.70	17
18	8.61	9.55	12.05	9.46	11.76	11.79	12.44	10.19	9.25	9.07	8.99	9.82	18
19	8.85	9.66	11.95	9.40	11.48	11.84	12.19	10.10	9.28	9.04	8.96	11.87	19
20	9.88E	9.97	11.56	9.32	11.69	12.08	12.00	10.17	9.32	9.00	8.91	11.69	20
21	10.93	9.74	11.17	9.37	12.29	11.97	11.87	10.25	11.37	9.01	8.89	11.47	21
22	10.19	9.64	11.00	9.28	12.35	11.89	11.78	10.30	10.44	8.97	8.88	11.90	22
23	9.91	9.50	11.02	9.20	12.20	11.77	11.63	10.19	10.32	8.97	9.10	11.58	23
24	9.56	9.36	10.81	9.30	11.76	12.19	11.55	10.12	10.11	8.93	9.06	11.40	24
25	9.51	9.30	10.53	9.44	11.40	12.00	11.45	10.08	9.92	8.91	8.97	11.08	25
26	9.40	9.17	10.35	9.36	11.22	11.99	11.38	10.03	9.81	9.16	9.42	12.88	26
27	9.21	9.62	10.17	9.33	11.52	11.85	11.32	9.97	9.67	9.00	9.18	11.77	27
28	9.09	10.46	10.01	9.72	12.15	12.03	11.26	9.96	9.58	8.96	9.09	11.38	28
29	8.91	10.76	9.87	9.70	12.85	12.13	11.32	9.95	9.53	8.90	9.03	10.92	29
30	8.84		9.49	9.49	13.35	12.24	11.20	9.94	9.54	8.85	8.98	10.73	30
31	8.79		9.50		13.22		11.25	9.82		8.83		10.50	31

SUMMARY FOR THE YEAR 1972

MAXIMUM DAILY WATER LEVEL, 13.64 FT ON JUL 13
MINIMUM DAILY WATER LEVEL, 8.42 FT ON JAN 15

TYPE OF GAUGE - MANUAL
LOCATION - LAT 49 05 30 N
LONG 122 02 10 W

E-ESTIMATED
NATURAL FLOW

WATER LEVELS ARE REFERRED TO ASSUMED DATUM.
APPLY 19.09 FT ADJUSTMENT TO CONVERT TO GEODETIC SURVEY OF CANADA DATUM.

VERNON CREEK AT INLET TO ELLISON LAKE - STATION NO. 08NM162

DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1972

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	3.3	6.6 E	7.5	79.1	18.1	173	44.5	5.1	12.8	4.6	11.6	10.8	1
2	3.4	7.8 E	8.1	82.3	26.5	151	41.3	5.4 E	6.4	9.9	12.4	4.4	2
3	3.2	8.7 E	6.7	82.3	28.9	121	39.6	5.8	7.2	10.2	12.0	4.0 E	3
4	4.1	9.1 E	2.7	88.8	34.3	104	40.1	2.7	8.1	9.9	4.5	6.4 E	4
5	5.8	8.0 E	3.0	91.6	37.4	98.1	39.7	2.2 E	16.1	10.1	5.8	10.5 E	5
6	4.4	4.7 E	8.8	92.2	39.0	91.0	30.0	1.8 E	12.6	8.6	12.5	12.9 E	6
7	3.7	5.1 E	25.2	89.5	44.1	86.7	13.8	1.5	13.4	4.1	12.7	12.5 E	7
8	3.4	6.5 E	39.2	84.2	49.2	83.8	10.3	1.6	17.2	3.9	13.1	12.0 E	8
9	3.4	8.0 E	11.2	82.1	50.8	79.3	12.5	1.7	13.8	4.0	12.7	4.0 E	9
10	4.9	8.3 E	10.4	63.8	54.4	71.0	9.7	1.5	15.5	9.5	13.2	3.6 E	10
11	7.7	6.4 E	4.8	27.1	62.9	71.8	7.8	1.4 E	19.8	9.8	5.8	5.5 E	11
12	5.2	5.3 E	5.9	26.2	69.4	74.0	15.6	1.3 E	18.2	11.2	4.7	10.5 E	12
13	6.2	5.5 E	11.6	26.3	76.4	76.9	20.8	1.3 E	17.3	11.7	4.9	10.3 E	13
14	7.1	6.6 E	12.0	25.4	89.2	71.7	17.5	1.4 E	17.2	6.9	11.7	10.4 E	14
15	5.4	9.9	12.3	17.9	96.3	67.8	14.1	1.5	14.6	5.4	10.6	9.6 E	15
16	6.3	9.2	13.8	17.3	85.6	67.3	11.0	2.2	7.3	11.4	10.8	3.4 E	16
17	11.7	9.3	15.2	23.6	89.3	61.5	6.9	4.8	7.2	10.9	11.4	2.9 E	17
18	11.0	8.5	19.1	23.0	80.7	59.6	4.1	13.6	12.6	9.8	5.1	5.0 E	18
19	10.4	2.8	19.3	24.1	61.1	56.9	4.0 E	10.5	11.3	9.6	4.6	9.1 A	19
20	8.9	2.2	24.5	28.1	62.0	57.0	3.9 E	12.0	10.9	7.6	9.4	9.6	20
21	8.8	8.4	38.2	29.4	74.1	55.4	3.8 E	21.3	14.5	4.5	10.4	9.5	21
22	3.4	8.8	61.2	19.6	93.4	54.3	3.7 E	22.6	12.9	4.9	10.4	6.8	22
23	3.3	9.3	70.9	15.3	142	57.0	3.6 E	18.2	7.6	9.5	11.8	2.3	23
24	8.7	8.9	72.5	21.3	135	59.7	3.5 E	16.7	6.8	10.1	11.8	2.2	24
25	9.3 E	9.0	74.3	21.8	126	58.8	3.5	14.5	12.3	10.5	4.9	2.3	25
26	10.2 E	2.4	76.5	21.8	128	58.5	4.7	5.6	13.3	10.0	4.6	2.8	26
27	11.2 E	3.2	78.6	22.4	131	57.5	6.4	3.9	12.2	10.4	10.5	6.5	27
28	11.5 E	8.6	75.8	25.9	141	55.5	3.4	7.8	12.1	4.3	9.2	7.7	28
29	5.6 E	7.9	76.2	20.5	159	52.6	1.4	4.7	12.2	3.9	10.7	6.7	29
30	4.8 E		77.6	17.0	120	49.5	1.6	8.2	4.9	8.4	11.3	2.1	30
31	5.7 E		76.6		162		4.8	11.2		9.9		1.9	31
TOTAL	202.0	205.0	1039.7	1289.9	2567.1	2282.2	427.6	214.0	368.3	255.5	285.1	208.2	TOTAL
MEAN	6.5	7.1	33.5	43.0	82.8	76.1	13.8	6.9	12.3	8.2	9.5	6.7	MEAN
AC FT	401	407	2060	2560	5090	4530	848	424	731	507	565	413	AC FT
MAX	11.7	9.9	78.6	92.2	162	173	44.5	22.6	19.8	11.7	13.2	12.9	MAX
MIN	3.2	2.2	2.7	15.3	18.1	49.5	1.4	1.3	4.9	3.9	4.5	1.9	MIN

SUMMARY FOR THE YEAR 1972

MEAN DISCHARGE, 25.5 CFS
TOTAL DISCHARGE, 18500 AC-FT
MAXIMUM DAILY DISCHARGE, 173 CFS ON JUN 1
MINIMUM DAILY DISCHARGE, 1.3 CFS ON AUG 12

MAXIMUM INSTANTANEOUS DISCHARGE
189 CFS AT 1530 PST ON MAY 31

TYPE OF GAUGE - RECORDING
LOCATION - LAT 50 00 18 N
LONG 119 23 09 W

A-MANUAL GAUGE

E-ESTIMATED

REGULATED

Figure 13. Sample page from "Surface Water Data" Publication.

BIG OTTER CREEK NEAR VIENNA - STATION NO. 02GC004

ANNUAL EXTREMES OF DISCHARGE IN CFS AND ANNUAL TOTAL DISCHARGE IN AC-FT

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE	MAXIMUM DAILY DISCHARGE	MINIMUM DAILY DISCHARGE	YEAR	TOTAL DISCHARGE
1948	---	---	---	1948	---
1949	---	3730 CFS ON FEB 16	41.0 CFS ON NOV 10	1949	170000 AC-FT
1950	---	4120 CFS ON APR 5	43.0 CFS ON OCT 6	1950	282000 AC-FT
1951	---	3400 CFS ON FEB 22	36.0 CFS ON SEP 10	1951	258000 AC-FT
1952	---	3040 CFS ON MAR 11	36.0 CFS ON AUG 7	1952	180000 AC-FT
1953	---	1700 CFS ON MAR 4	51.0 CFS ON OCT 5	1953	113000 AC-FT
1954	---	---	---	1954	---
1955	---	2530 CFS ON MAR 1	39.0 CFS ON JUL 15	1955	186000 AC-FT
1956	---	2520 CFS ON MAR 3	80.0 CFS ON AUG 1	1956	223000 AC-FT
1957	---	2070 CFS ON APR 6	92.0 CFS ON AUG 19	1957	216000 AC-FT
1958	---	565 CFS ON APR 10	49.0 CFS ON SEP 3	1958	120000 AC-FT
1959	---	1230 CFS ON APR 4	57.0 CFS ON JUL 16	1959	209000 AC-FT
1960	---	2710 CFS ON MAR 30	51.0 CFS ON SEP 29	1960	198000 AC-FT
1961	---	1790 CFS ON APR 26	47.0 CFS ON FEB 1	1961	168000 AC-FT
1962	---	---	---	1962	---
1963	---	---	---	1963	---
1964	995 CFS AT 0300 EST ON AUG 24	839 CFS ON AUG 24	25.0 CFS ON AUG 1	1964	118000 AC-FT
1965	7410 CFS AT 0500 EST ON MAR 7	6400 CFS ON MAR 6	39.6 CFS ON JUL 30	1965	236000 AC-FT
1966	2080 CFS AT 1030 EST ON DEC 8	2040 CFS ON DEC 8	41.4 CFS ON JUL 22	1966	177000 AC-FT
1967	1850 CFS AT 0300 EST ON DEC 22	1800 CFS ON DEC 22	57.0 CFS ON SEP 11	1967	197000 AC-FT
1968	5340 CFS AT 2330 EST ON FEB 3	3700 CFS ON FEB 3	64.0 CFS ON JUL 28	1968	206000 AC-FT
1969	6180 CFS AT 2100 EST ON JAN 30	5110 CFS ON JAN 31	73.3 CFS ON SEP 14	1969	248000 AC-FT
1970	1480 CFS AT 1556 EST ON APR 3	1420 CFS ON APR 3	44.1 CFS ON AUG 10	1970	144000 AC-FT
	EXTREMES OF DISCHARGE FOR THE PERIOD OF RECORD			MEAN	192000 AC-FT

MAX. INST. DISCHARGE IS 7410 CFS ON MAR 7 1965 AT 0500 EST
MAX. DAILY DISCHARGE IS 6400 CFS ON MAR 6 1965
MIN. DAILY DISCHARGE IS 25.0 CFS ON AUG 1 1964

BIGHEAD RIVER NEAR MEAFORD - STATION NO. 02FB010

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC FEET PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1957	---	---	---	---	88.5	69.9	63.6	23.5	122	132	218	318	---
1958	135	107	178	264	63.2	39.1	23.8	19.2	18.5	22.7	36.9	53.7	79.8
1959	76.4	72.9	251	655	192	60.5	32.6	28.3	28.9	47.1	208	213	155
1960	188	136	165	626	417	108	41.4	29.4	26.4	31.7	74.6	59.5	158
1961	69.5	204	399	340	165	114	47.2	43.8	42.6	30.6	119	250	152
1962	107	129	334	365	95.0	29.4	21.3	14.9	18.5	34.0	70.6	147	114
1963	55.0	45.4	430	251	285	66.8	30.2	29.8	21.6	24.0	83.2	54.5	115
1964	196	116	279	198	78.1	30.4	23.1	18.5	14.8	20.9	21.5	101	91.6
1965	121	249	113	697	198	51.2	31.2	23.9	22.2	45.6	89.5	292	160
1966	163	275	304	154	77.1	39.9	17.6	17.9	14.1	18.2	42.9	195	109
1967	185	116	258	450	109	118	123	64.5	54.6	142	367	324	193
1968	148	358	453	264	134	63.2	30.4	93.5	57.2	69.1	201	298	180
1969	234	200	293	574	318	137	62.6	37.5	37.5	66.0	121	106	182
1970	84.4	96.3	150	644	149	52.2	65.0	29.0	61.0	99.2	121	168	143
MEAN	136	162	277	422	169	70.0	43.8	33.8	38.6	55.9	127	184	141

BIGHEAD RIVER NEAR MEAFORD - STATION NO. 02FB010

ANNUAL EXTREMES OF DISCHARGE IN CFS AND ANNUAL TOTAL DISCHARGE IN AC-FT

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE	MAXIMUM DAILY DISCHARGE	MINIMUM DAILY DISCHARGE	YEAR	TOTAL DISCHARGE
1957	---	---	---	1957	---
1958	---	605 CFS ON APR 1	11.0 CFS ON SEP 15	1958	57800 AC-FT
1959	---	1390 CFS ON APR 3	14.0 CFS ON SEP 8	1959	113000 AC-FT
1960	---	2550 CFS ON APR 3	16.5 CFS ON OCT 17	1960	115000 AC-FT
1961	---	1280 CFS ON MAR 28	18.0 CFS ON AUG 21	1961	110000 AC-FT
1962	---	1750 CFS ON MAR 30	6.5 CFS ON AUG 20	1962	82200 AC-FT
1963	---	3100 CFS ON MAR 26	13.2 CFS ON SEP 9	1963	83500 AC-FT
1964	---	1010 CFS ON MAR 5	10.3 CFS ON SEP 14	1964	66500 AC-FT
1965	---	1800 CFS ON APR 12	12.6 CFS ON AUG 23	1965	116000 AC-FT
1966	---	2100 CFS ON FEB 11	4.6 CFS ON SEP 19	1966	79000 AC-FT
1967	2260 CFS AT 0700 EST ON APR 1	1980 CFS ON APR 1	20.5 CFS ON SEP 17	1967	139000 AC-FT
1968	2770 CFS AT 1745 EST ON FEB 2	2230 CFS ON FEB 2	15.2 CFS ON AUG 12	1968	131000 AC-FT
1969	1550 CFS AT 0937 EST ON APR 5	1400 CFS ON APR 5	15.2 CFS ON SEP 1	1969	132000 AC-FT
1970	1800 CFS AT 1903 EST ON APR 9	1650 CFS ON APR 9	19.2 CFS ON AUG 15	1970	103000 AC-FT
	EXTREMES OF DISCHARGE FOR THE PERIOD OF RECORD			MEAN	102000 AC-FT

MAX. INST. DISCHARGE IS 2770 CFS ON FEB 2 1968 AT 1745 EST
MAX. DAILY DISCHARGE IS 3100 CFS ON MAR 26 1963
MIN. DAILY DISCHARGE IS 4.6 CFS ON SEP 19 1966

BLACK CREEK AT SCARLETT ROAD - STATION NO. 02HC027

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC FEET PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1966	---	---	---	---	---	---	---	8.1	10.8	9.6	18.4	26.7	---
1967	13.9	12.0	37.6	36.4	17.1	43.3	23.7	14.2	20.8	20.5	20.0	31.1	24.3
1968	17.6	46.9	57.5	18.7	22.9	16.6	12.1	33.7	17.1	14.1	32.7	21.4	25.9
1969	43.6	14.8	27.8	41.0	29.2	14.4	21.5	17.4	10.7	18.7	27.9	15.7	23.6
1970	10.4	17.4	68.2	41.6	23.4	14.3	22.1	27.7	20.7	17.6	22.5	21.9	25.7
MEAN	21.4	22.8	47.8	34.4	23.2	22.2	19.9	20.2	16.0	16.1	24.3	23.4	24.9

Figure 14. Sample page from "Historical Streamflow Summary" Publication.

Location: Lat. 49° 07' 39", long. 128° 18' 08", British Columbia, on north bank, fifty feet west of the Canadian Pacific Railway Bridge.
Gauge: Recording.
Period of Record: Suspended sediment load, May 1965 to December 1969.
Extremes Recorded: Maximum daily suspended sediment load, 781,000 tons/day on June 7, 1967.
Minimum daily suspended sediment load, 471 tons/day on March 2, 1966.

Monthly Mean Suspended Sediment Load in Tons per Day

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1965						260,000	89,500	44,600	19,000	32,000	11,600	3,060	-
1966	2,200	929	2,910	55,200	235,000	219,000	117,000	51,200	14,000	13,400	5,300	10,600	60,900
1967	2,310	1,090	1,740	16,900	263,000	579,000	4,902,300	1,183,700	421,270	17,300	16,600	5,050	92,800
1968	21,000	6,510	18,700	12,900	223,000	251,000	209,000	48,200	25,000	9,760	14,300	3,230	70,600
1969	2,900	2,440	1,570	64,100	162,000	212,000	52,500	29,000	19,300	12,000	8,510	3,370	47,800

Suspended Sediment for 1969

Day	January				February				March			
	Water Temp. (°C)	Daily Discharge (cfs)	Suspended Sediment Mean Concentration (mg/litre)	Suspended Sediment Tons per day	Water Temp. (°C)	Daily Discharge (cfs)	Suspended Sediment Mean Concentration (mg/litre)	Suspended Sediment Tons per day	Water Temp. (°C)	Daily Discharge (cfs)	Suspended Sediment Mean Concentration (mg/litre)	Suspended Sediment Tons per day
1		43,100	19	2,210		39,200	11	1,160		35,500	17	1,630
2		44,400	19	2,280		40,100	13	1,410		34,500	17	1,580
3		45,000	20	2,430		41,600	16	1,800		34,500	14S	1,300
4		42,500	59	6,770		42,600	18	2,070	0.5	34,500	13S	1,210
5		49,800	106	14,300		44,100	18	2,140		35,000	14	1,320
6	6.5	54,600	86S	12,700		44,500	18	2,160		35,600	14	1,350
7		53,500	38	5,490		43,800	21	2,480	0.5	34,900	16S	1,510
8		54,800	32	4,730		42,900	28	3,240		35,400	15	1,430
9	0.5	53,300	31S	4,460		44,200	35	4,180	2.0	35,100	15S	1,420
10		53,000	27	3,860		43,400	31	3,630		33,500	14	1,270
11		52,700	21	2,990		42,800	31	3,580		33,500	13	1,180
12		51,200	19	2,630		43,800	27	3,190	2.0	34,000	12S	1,100
13		48,500	15	1,960		43,700	22	2,600		33,900	11	1,010
14		46,800	15	1,900		43,300	22	2,570		33,200	11	986
15	0.5	44,000	15S	1,780		42,400	26	2,980	2.0	32,400	11S	962
16		42,200	15	1,710		42,100	31	3,520		33,700	13	1,180
17		43,400	15	1,760		40,500	35	3,830		34,600	15	1,400
18		43,400	15	1,760		39,300	37	3,930	3.0	37,600	19S	1,930
19		43,300	14	1,640	0.5	39,400	35S	3,720		38,800	22S	2,300
20		43,900	13	1,540	0.5	39,900	17S	1,830		38,700	21	2,190
21		42,400	12	1,370		39.800	11	1,180		38,700	20	2,090
22		42,200	11	1,250	0.5	39,100	17S	1,790		38,400	18	1,870
23		41,700	9	1,010		38,100	18	1,850	3.5	40,800	17S	1,870
24		41,800	8	903	0.5	37,600	15S	1,520		40,400	16	1,750
25	0.5	41,700	8S	901		36,900	13S	1,300	4.0	39,800	16S	1,720
26		41,100	7	777		36,700	14	1,390		39,700	15	1,610
27		40,900	7	773	0.5	36,400	16S	1,570		39,300	15	1,590
28		40,000	8	864		35,900	17	1,650	4.5	41,000	15S	1,660
29		39,600	9	962		-	-	-		42,000	16	1,810
30		39,100	10	1,060		-	-	-		42,800	18	2,080
31		38,700	11	1,150		-	-	-	5.0	45,200	19S	2,320
Total		1,402,600	694	89,920		1,144,100	613	68,270		1,147,000	482	48,628
Mean		45,200	22	2,900		40,900	22	2,440		37,000	16	1,570

S - Sample(s) collected this day

Figure 15. Sample page from "Sediment Data" Publication.

Instruction Manuals

Instruction manuals are continuously under review and are revised as new or improved procedures are developed. Some procedures and methods now in use are covered by memoranda only, although preparation of instruction manuals is either underway or is planned. Documentation of existing computer programs is also underway and is a major activity.

The following is a list of internal instruction manuals that have been developed to standardize and explain procedures related to the computation of basic hydrometric data collected by the Water Resources Branch.

Automated Drainage Area Computations

Procedures for digitizing drainage boundary delineations from maps to calculate automatically the drainage area at a gauging station are outlined. This procedure may be used also for other area calculations.

Automated Manual Gauge Computations

Instructions for automatic computation of daily discharges and/or water levels for stations equipped with manual gauges only are outlined. Output options are the same as for the STREAM program.

Automated Streamflow Computations

Procedures for digitizing water level recorder charts to obtain punched cards containing X-Y coordinates are outlined. These cards, along with card decks defining the stage-discharge relationship, gauge and shift corrections and updating corrections are processed by a digital computer (using the STREAM computer program) to obtain daily gauge heights and daily discharges. Output options are the same as for the MANUAL program.

HYDEX

Procedures for submitting descriptive information for all gauging stations operated during the history of the Water Survey of Canada, and procedures for the storage and retrieval of this information by automated techniques are outlined.

Hydrometric Data Review Procedures

Criteria and procedures for use in a review of historical streamflow data to discover and correct, as far as possible, significant errors in the existing records are outlined.

Hydrometric Office Procedures

This manual contains detailed office procedures to be followed in the computation and compilation of daily water levels and daily discharges and the preparation of manuscript for publication.

Conclusions and Future Plans

CONCLUSIONS

Hydrometric data have been collected since 1908 and published (usually annually) in a variety of formats in over 200 publications. In 1966, a decision was made to automate the system by (a) computation of streamflow data using a digitizer, and (b) storage of historical daily discharges and water levels on magnetic tape. After a thorough study of alternatives, it was decided to continue collecting graphical water level charts and to introduce automation after the field data collection stage.

With the implementation of automated computation and publication procedures, the delay between the collection of hydrometric data and availability of the data in published form has been reduced from 2 — 3 years to 10 months or less. Data are also available to users on punched cards or magnetic tape. The annual cost of producing data publications is about $75 per station-year, including only the costs for printing and for computer time at Ottawa and the Districts. The net saving in manpower is difficult to estimate but is probably in the order of 20 man-years annually.

The intangible benefits derived from automation include: (a) data virtually free from mathematical and typographical errors; (b) data more readily accessible for computer processing; and (c) improved employee morale because of reduction in routine, monotonous, repetitive work.

Although there was some negative reaction at the outset, the program is now accepted with enthusiasm.

Perhaps the most critical factor in the development and implementation of the overall system was the selection and the performance of computer programmers. Instruction manuals and documentation of computer programs were and continue to be very important. It should be recognized also that the success of the development of the program was due in no small measure to the high level of cooperation, participation and support on the part of the technicians, engineers, clerks and stenographers involved.

FUTURE PLANS

A minicomputer/tape drive/plotter system has been interfaced with a buffered card punch/digitizer system for investigating the feasibility of more efficient data computation techniques, particularly for digitizer applications.

Plans are under way to automate the Surface Water Data Reference Index and the Sediment Data publications.

The goal is to have hydrometric data available to users in published form and on punched cards or magnetic tape, six months after the end of the year in which the data were collected.